A study of the distribution of the bronchial tree, the pulmonary artery and the pulmonary vein in the lungs of the sheep.

Thesis for the Degree of Doctor of Philosophy

by

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Contents.

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Introduction.

The lungs in mammals are the essential organs of respiration. By respiration is meant the inhalation of air for its oxygen content and the expiration of carbon dioxide and moisture, the oxygen is transported to the tissues by the bloodstream and exchanged there for carbon dioxide.

The lungs are thought to have evolved first in fishes during the Devonian period to meet the long periods of drought which they had to withstand, and they are still to be found in the African lung-fish and a few modern tropical fish. The earlier theory is that the lungs have developed from the swim bladder which is found in the actinopterygian fishes, but more recent evidence would seem to indicate that the reverse is the case (Romer, 1949).

In fishes the lungs are in the form of air filled vesicles; ascending the vertebrate ladder, in amphibians the lungs are in the form of bilobed sacs connected to the pharynx by a tube, while in reptiles the lungs represent a transition between the sac-like lungs of amphibians and the more highly developed type of lungs found in birds and mammals.

In mammals the lungs have undergone a great increase in the number of bronchi, while the alveoli are more numerous and their arrangement is more complex; the lungs are more highly vascularised and the muscles concerned with respiration are well developed.

Within the Class - Mammalia, however, the lungs present many/

many different types of bronchial tree; for example, in Hystrix cristata, the European Porcupine, and Taxidea americana, the American Badger, the trachea enlarges to form a lacuna or bulla and the bronchi arise from the bulla. (Plate I, figs. 1 & 2). In Canis familiaris, the dog, the trachea divides into two main bronchi and from these smaller bronchi arise; on the right side, a bronchus arises above or cranial to the point at which the pulmonary artery crosses the main bronchus and so is known as an eparterial bronchus, as opposed to the remaining bronchi on the right and left sides which arise below the point at which the pulmonary arteries cross the main bronchi and are known as hyparterial bronchi. (Plate I, fig. 3). In Cebus niger, the Capuchian monkey, there are two eparterial bronchi, right and left, arising from the right and left main bronchi respectively (Plate I, fig. 4). In the Sub-order Artiodactyla, an eparterial bronchus arises from the wall of the trachea on the right side and passes to the apical lobe of the right lung (Plate XLI).

Huntington (1920) has attributed these variations to the morphogenetic principles and the physiological factors operative during the pulmonary evolution. That is to say that, during the evolution of the lung, the entoderm had the potential to develop bronchial buds from any point on the entodermal surface and that the bronchial type which was evolved was the one best suited to the environmental conditions at the time. The tree then became fixed for that form by heredity provided that the respiratory factor in the environment/

environment remained unaltered. The physiological factors which have affected the pulmonary evolution may be listed as follows.

1) The increase in oxygenation and resultant metabolic changes following the change from the poikilothermal amphibians and reptiles to the homeothermal birds and mammals.

2) Increased size and functional activity which require a greater inhalation of oxygen and exhalation of carbon dioxide, and

3) Changes in general environment.

Little detailed work appears to have been carried out on the lungs of the sheep. Several authors have studied the early development of the lungs, and Aeby (1880) in his survey of the bronchial tree has furnished us with a few measurements on the width and distance between bronchi in the lungs of sheep.

Narath (1901) made a survey of the bronchial tree and pulmonary blood vessels in the lungs of the artiodactyls in which he examined thirty lungs belonging to eighteen species, including a set from ovis aries. His survey included a description of the external form of the lungs and a description of the main branches of the bronchial tree and pulmonary blood vessels. Although the field of his survey was extensive his findings cannot be regarded as conclusive because, the number of specimens examined from each species was too small.

Bressou and Vladutiu (1939) studied seventy-two lungs from eleven species of domestic animals, including ten lungs

from/

from the sheep, with the intention of establishing a general type of systemisation in the domestic animals for the main branches of the bronchial tree, and for the areas which they ventilate.

However, as far as is known, no attempt has been made to make a specialised study of the bronchial tree, the pulmonary artery and the pulmonary vein in the sheep. The purpose of this thesis is to summarise the work which has been carried out on the development of the lung of the sheep, and then to describe the lungs with special reference to (a) the independent areas into which they can be divided, and (b) the bronchial tree, pulmonary artery and vein, with reference to the above areas.

Summary.

Each section of the work is summarised separately and this is intended as a brief summary of the work as a whole.

1) A description of the early development of the bronchial tree in the sheep is given based on the findings of Nicolas and Dimitrova (1897) and d'Hardiviller (1897) in the sheep, and of Flint (1906) in the pig. In the summary of the findings the nomenclature used in the description of the adult bronchial tree is substituted for that used by these workers.

2) The findings of Flint (1906) on the early development of the pulmonary artery and vein in the pig are recorded, because it is thought that, with certain exceptions, these vessels will follow similar lines of development in the sheep.

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3) The external appearance of the lungs is described. The term "pulmonary lobe" is defined, and based on this definition the right lung is divided into four lobes, an apical, a cardiac, an intermediate and a diaphragmatic, and the left lung is divided into two lobes, an apical-cardiac and a diaphragmatic.

4) An analysis is made of the variations which occurred in the external form of the lobes in the lungs of one hundred and fifty sheep, and possible explanations for these variations are suggested.

5) The number of subdivisions of the bronchial tree which occur between a segmental bronchus and a respiratory bronchiole are recorded in the case of three segments. The number of bronchial generations is found to be about sixteen and the number of bronchiolar generations about fifteen.

6) The broncho-pulmonary segments are described following a survey of the lungs of fifteen sheep; the right lung is found to consist of twelve segments and the left lung of eight segments. The basic international nomenclature accepted by the Thoracic Society for the human lung is adopted whenever possible.

7) Following a survey of the lungs of fifty sheep, the main branches of the bronchial tree are described, with attention to the areas which they ventilate.

8) The large branches of the pulmonary arteries are described, following a study of the lungs of fifteen sheep, with reference to the areas of the lung which they supply, and their relations to the bronchi are given.

9)/

9) The main tributaries of the pulmonary veins are described with attention to the areas which they drain. They were studied in the lungs of thirteen sheep.

10) A short discussion on the importance of a well defined pulmonary terminology is included.

Material & Methods.

Methods of demonstrating the bronchial tree and pulmonary blood vessels.

A. Dissection.

The bronchial tree was first studied by the dissection of fresh lungs. It was found that the lung tissue was more easily dissected away from the bronchi if the lungs had been frozen first and then allowed to thaw out. Ten sets of lungs were examined in this way and from these dissections a good knowledge of the branching of the bronchial tree and the position of the bronchi within the lung tissue was obtained.

Approximately fifteen dissections were carried out on fresh specimens in which the pulmonary arteries and veins had been injected with warm 15% gelatin solutions using an 8oz metal syringe; in some of these specimens, the bronchopulmonary segments were injected first with coloured gelatin solutions using the method described later (Plate II). These dissections allowed the relations of the arteries and veins to the bronchial tree to be noted and also indicated the position of the veins in respect to the connective tissue planes.

The disadvantage of the dissection of fresh lungs was that/

that the shape was lost and consequently it was difficult to orientate the structures. This was overcome by fixing the lungs "in situ" by filling the trachea and bronchial tree with 10% formalin, or by inflating lungs which had been removed from the thorax with 10% formalin into the bronchial tree and allowing them to harden.

More permanent and better results were obtained by the preparation of corrosion casts of the bronchial tree and blood vessels, or by the preparation of serial sections of a lobe.

B. Corrosion casts.

The principle behind the making of corrosion casts is the injection of a mass into the bronchial tree or blood vessels and the subsequent solidification of the injection mass. The mass must be unaffected by the macerating action of concentrated acid or strong alkali on the lung tissue and so provide a cast which is an accurate replica of the lumen of the bronchial tree or blood vessels. It should not require any special method of preservation and should be able to withstand a fair amount of handling.

Two methods were employed to inject the bronchial tree and pulmonary blood vessels. When it was possible to obtain the whole carcase the lungs were injected "in situ", as in this method the shape of the lungs can be retained accurately. In the majority of cases, however, the lungs had to be removed from the thorax before injection, and in these cases, the lungs were suspended in a vacuum chamber so that they were injected in a distended state, and this helped them to return to their correct/

correct shape. Thirty-five lungs were studied by means of corrosion casts.

Apparatus - Glass Filter funnel - 15cm diameter.
Air pump and pressure chamber.
Pressure bottle - 250cc.
Mercury manometer.
Rubber pressure tubing & glass cannulas.
Vacuum tank and vacuum pump.

The bronchial tree was injected by gravity feed. A cork with a glass tube in the centre was tied into the trachea, and the glass tube was then connected to the filter funnel by a piece of rubber tubing 36 inches long. The filter funnel was fixed to a retort stand so that it could be raised or lowered at will.

The blood vessels were injected under pressure. The air pump and pressure chamber (A) were provided by using an Edward's Type IV compressor and vacuum pump; this was connected by rubber pressure tubing to a mercury manometer (B) and to the pressure bottle (C). The pressure bottle which held the injection mass had a wide mouth and a tightly fitting rubber stopper. Two glass tubes passed through the rubber stopper, one tube extended to within $\frac{1}{4}$" of the bottom of the bottle, while the other passed through the stopper. Each tube had a right angle bend as it left the bottle. The short tube was connected to the pump and the long tube was connected by rubber pressure tubing to the glass cannula which was tied into the blood vessel (Plate III, fig. 1).

When the lungs were removed from the thorax their shape was/

was lost, and for this reason they were placed in a vacuum tank and subjected to a negative pressure of 10mm of mercury so that they were inflated and regained their normal shape.

This procedure was first used by Moolten (1935) for the fixation of the lungs, and modified for injection purposes by Liebow, Hales, Lindskog and Bloomer (1937), the principle of whose method was adopted; the vacuum tank was a large metal tank (A) measuring 47cm in depth, 45cm in length and 42cm in width. A flat perspex sheet 6mm thick was used as a lid, and in this lid three holes with a diameter of 3,3cms were bored. One hole (C) was bored in the centre of the lid, and the other two (B & D) on either side of the centre hole and about 10cm from it (Plate III, fig. 2).

Each hole had a tightly fitting rubber cork, the side corks contained a central glass tube, while the centre tube contained a threaded brass tube. The lungs were suspended from the brass tube in the centre cork by a short piece of rubber tubing which was attached to a threaded brass tube in the cork in the trachea. The glass tube in one of the side corks (B) was connected on the outside of the tank to the pressure bottle containing the injection mass, and on the inside of the tank, to the cannula tied into the pulmonary vessel. The glass tube in the other side cork (D) was connected to the mercury manometer (E) and to the vacuum pump (Edward's Type IV compressor and vacuum pump) (Plate III, fig. 2).

The perspex lid was sealed by using Secomastic, a joint-sealing/

sealing compound supplied by Secomastic Limited, 11, Upper Brook Street, Park Lane, London, W. 1.

Materials. - Three types of injection mass were used in the preparation of the corrosion casts; celloidin solutions, Vinylite resin solutions and Marco Resin SB 26c solutions. The preparation of the celloidin injection solutions has been described by Hinman, Morison and Lee-Brown (1923); while Marquis (1929) has described the use of celloidin solutions in the preparation of corrosion casts of the lung. The materials required were:

Acetone (chemically pure).

Celloidin.

Used cellulose nitrate X-ray films.

Camphor.

Three celloidin solutions were used; a 4% solution for fine injections consisting of:

Acetone	100cc.
Celloidin	4grms.
Camphor	3grms.

A 10% solution consisting of:

Acetone	100cc.
Cellulose nitrate film	10grms.
Camphor	8grms.

And a 20% solution consisting of:

Acetone	100cc.
Cellulose nitrate film	20grms.
Camphor	15grms.

The/

The solutions were prepared by adding to the acetone the celloidin, or cellulose nitrate film, which had been washed to remove the emulsion, dried and cut into strips, and thoroughly shaking till dissolved. When completely dissolved the camphor was added, the purpose of the camphor being to prevent the final cast from becoming too brittle. The solutions were then filtered through glass wool under a vacuum and stored in a well-stoppered bottle to prevent evaporation.

Vinylite resin solution as an injection mass has the following advantages over celloidin solution: the final cast is much less brittle, the mass is more easily prepared, and, now that cellulose nitrate is no longer used for X-ray films, it is very much cheaper. (Vinylite resin solution was first used by Narat, Loef and Narat (1936)). The materials used were acetone, and Vinylite resin VYHH as supplied by Bakelite Limited, 187, Broad Street, Birmingham; two solutions were used, 12.5% solution by weight in acetone which is suitable for the blood vessels, and an 18% solution by weight in acetone which is suitable for the bronchial tree.

Both the celloidin and Vinylite solutions were coloured by using the dyestuffs Monolite Fast Scarlet Paste R.M.V.S. and Monastral Fast Blue Paste B.V.S. as supplied by the Imperial Chemical Industries.

The above injection masses solidify by solvent evaporation, and this process is speeded up by the presence of water which removes the acetone. They are virtually unaffect -ed by the action of concentrated hydrochloric acid although the/

the prolonged immersion of celloidin does tend to make it brittle. The disadvantage of the above injection masses is that some shrinkage takes place, and this must be remembered during the injection and when reading the cast.

Procedure of Injection. - The following procedure was adopted to inject the bronchial tree and pulmonary blood vessels when the lungs were "in situ".

The sheep was anaesthetised, using 'Nembutal', and then bled-out by cutting the carotid artery; when bleeding was complete the carotid artery was ligatured above and below the incision. Then the abdomen was opened by incising along the mid-line to avoid cutting small blood vessels and consequent leakage during the injection; the abdominal aorta and caudal vena cava were located and then a glass cannula was tied into the aorta cranial to the coeliac axis, and another into the vena cava cranial to the renal arteries. (If a cast of the bronchial tree alone was required, it was not necessary to open the abdomen and wash out the blood vessels).

The pulmonary artery and vein were washed out using warm normal saline solution before the blood was able to clot. The saline was pumped into the aorta and the blood was allowed to escape from the caudal vena cava; the washing was continued until the outflow from the venous side was clear. The advantages of washing out the blood vessels with normal saline were as follows:

1) The blood and any blood clots which might prevent the injection mass entering the small vessels were removed.

2) Better casts were obtained because the large vessels retained/

retained their rounded appearance, and

3) The base was more rapidly precipitated out of the acetone solvent in the presence of the moisture in the vessels.

After the blood vessels had been washed out, the sheep was laid on its back on a table and held in position by tying its four legs to the table. The neck was incised along the mid-line and the underlying muscles were cut through to reveal the trachea. Then the trachea was freed from the surrounding connective tissue and the bronchial tree was washed out with water to remove any mucous etc., which might prevent the injection mass reaching a particular part of the tree; the water was poured into the trachea and then the lungs were allowed to drain.

To inject the bronchial tree, the trachea was filled with the injection mass using either 10% celloidin solution or 18% Vinylite solution; this was done before the trachea was connected up to the gravity feed to allow part of the large quantity of air which is present in the bronchial tree to escape. After this a cork containing a central glass tube was tied into the trachea and the glass tube was connected up to the filter funnel containing the injection mass by a piece of rubber tubing. It was important to fill the rubber tubing with the injection mass before it was connected to the cork in the trachea to prevent air being carried into the bronchial tree.

At first the funnel was held at a height of 12 inches above the lungs, then, as the rate of flow of the injection mass decreased, the funnel was gradually raised to reach a final/

final height of 36 inches above the lungs. When using the celloidin injection mass, the 10% solution was used to start the injection, because it penetrated to the smaller bronchi and bronchioles, and then it was replaced by 20% solution which was thicker and did not penetrate so far, but caused less shrinkage. If a coarse cast were desired then the 20% solution was used from the start. When using the Vinylite injection mass, it was found that an 18% solution by weight in acetone was very satisfactory for the injection of the bronchial tree.

The sheep was turned over regularly so that the bronchial tree had every opportunity to fill evenly and completely, and the injection was continued for at least twentyfour hours as this allowed the bronchi to be refilled where shrinkage had taken place. It was very important to cover the top of the filter funnel to prevent the evaporation of the acetone with the consequent thickening of the solution. On completion of the injection, the rubber tubing was clamped just above the trachea.

The pulmonary veins were injected with the 4% celloidin solution followed by the 10% celloidin solution, or with the 12.5% solution of Vinylite. The apparatus was set up as described above with either the 4% celloidin solution or the 12.5% Vinylite solution in the pressure bottle (C) (Plate III, fig. 1). The pressure bottle was connected by a piece of rubber pressure tubing to the cannula which had been tied into the abdominal aorta, but first, to avoid pumping air into the vessels, the rubber tube was filled with the injection solution./

solution. The injection mass was pumped into the aorta and passed to the left ventricle of the heart; from there it went to the left atrium, and so to the pulmonary veins. Initially, a pressure of 80 - 100mm of mercury was used, and as the rate of flow of the injection mass slowed down, the pressure was increased gradually to 180mm of mercury. The pressure was maintained at this level for 12 hours when the rubber tubing was clamped near the cannula; by maintaining the pressure over a long period, the ultimate shrinkage in the vessels was reduced. When using celloidin, the 4% solution was used initially to ensure the injection of the fine vessels, but, when the injection rate slowed down, it was replaced by the 10% solution which causes less shrinkage.

When the pressure bottle was refilled it was important to prevent air from entering the long tube; after the rubber tubing had been clamped on either side of the pressure bottle, the rubber cork was removed, the bottle quickly filled and the cork replaced. If any air entered the long glass tube in the pressure bottle, it was removed by turning the pressure bottle upside down after it had been refilled and allowing the air to rise up out of the tube.

The arteries were injected by pumping the injection mass through the caudal vena cava to the right atrium; from there it passed to the right ventricle, and so to the pulmonary arteries. The 4% celloidin solution followed by the 10% solution, or 12.5% solution of vinylite, was used and the same method described for the veins was adopted; an initial pressure of 120mm of mercury was used and this was gradually increased/

increased to a pressure of 220mm of mercury.

After the injections had been completed, the lungs were left for a further 24 hours to allow the injection mass to harden and then they were placed in a tank containing cold water for a further 24 hours to complete the hardening process. Following this, they were floated in a tank containing concentrated hydrochloric acid where they remained until the acid had macerated the lung tissue; it was important to ensure that the lungs were able to float in the acid without touching the sides of the tank, to prevent their shape being spoiled.

The macerated tissue was washed away from the cast using a fine jet of water; if any lung tissue remained after washing, the lungs were replaced in the acid for several hours and then rewashed. This process was continued until the cast was quite clean, and it was then placed in a tank of cold water for two to three days to remove all traces of the acid. The cast was then dried and either mounted or stored in a box (Plate IV).

When the carcase was not available and the lungs had to be removed from the thorax, the following procedure was adopted. The lungs were removed carefully so that the pulmonary pleura was not damaged in any way. If the blood vessels were to be injected, the heart was removed with the lungs without incising the pericardium, to avoid the risk of injury to the heart and pulmonary vessels.

The lungs were washed quickly in water to remove any excess blood and then, if either a cast of the pulmonary arteries/

arteries or veins was required, the aorta and the pulmonary artery were dissected out carefully. A glass cannula was tied securely into the pulmonary artery as close as possible to the conus arteriosus, and another cannula was tied into the aorta close to the heart. The pulmonary blood vessels were then irrigated with warm normal saline to remove all the blood and blood clots; the saline was pumped into the pulmonary artery until the outflow from the aorta was quite clear. After this, the bronchial tree was washed to remove any mucous etc. by pouring water into the trachea and then allowing the lungs to drain.

The trachea was cut across so that there was sufficient length left for the injection, but not enough to cause the lungs to rest on the floor of the vacuum tank. The right and left apical lobes were kept in position by stitching them with cotton thread to the connective tissue surrounding the trachea. A cork with a central threaded brass tube was tied into the trachea, and a piece of rubber tubing was tightly attached by wire to the brass tube in the cork and to the brass tube in the centre cork (C) of the perspex lid. The cannula in either the pulmonary artery or the aorta, depending on the vessels to be injected, was connected by rubber pressure tubing to one of the side corks (B) in the perspex lid (Plate III, fig. 2). The lungs were then lifted into the tank and the lid was sealed in position using secomastic. The side cork (D) was connected to the vacuum pump (F), and the centre cork was connected to the filter funnel by a piece of rubber tubing which had previously been filled with the injection mass./

mass.

The injection mass was allowed to flow into the bronchial tree before the vacuum pump was started, so that the flow of the mass into the lungs was not too sudden and excessive. The filter funnel was held initially at a height of 12 inches above the lungs and then gradually raised to a height of 24 inches, as the flow of the injection mass slowed down. When in the vacuum the lungs tended to return to normal shape and this encouraged the complete filling of the bronchial tree; the filling of the bronchial tree was continued for 24 hours with the lungs in the vacuum, and then the injection was then allowed to continue without the vacuum, while the vessels were injected.

The pulmonary arteries and veins were injected adopting the same procedure, with regard to solutions and pressures, that was used in the "in situ" method; if it was desired to inject both the arteries and the veins in the vacuum tank, the lid had to be lifted to connect the cannula in the vessel to the cork in the lid with a piece of rubber tubing.

After the injections had been completed, the rubber tubes were tightly clamped, and the lungs were floated in a tank of cold water for 24 hours to ensure complete hardening of the injection mass. The lungs were then placed in concentrated hydrochloric acid and the preparation of the casts completed as described above (Plate V).

An alternative method was used to prepare coarse casts of the bronchial tree of the lungs of lambs from three to four days old. Marco-resin SB 26c as supplied by Cromwell

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& Co. Ltd., Bishop Stortford, Herts. was employed in this method.

<u>Materials</u> - Marco-resin SB 26c.

Chalk.

Strong solution of Sodium Sulphide.

Marco-resin is a cold water clear polyester which sets when it undergoes polymerisation. The resin before polymerisation is liquid with a high specific gravity; it flows into the alveoli giving a very complete cast of the bronchial tree and in some cases a solid cast of the lungs. It was found that the addition of chalk to the resin acted as a filler and prevented the complete injection of the bronchial tree, in fact, the extent of the injection could be controlled by the amount of chalk added.

To produce coarse casts of the bronchial tree the injection mass was prepared as follows:

500cc	Solution A.
70cc	" B.
70cc	" C.
12oz	Chalk.

Solution C is a plasticiser and controls the hardness of the polymerised injection mass. The three solutions were mixed together and then added to the chalk; all the lumps were removed by mixing with a pestle and mortar. The injection mass had to be prepared immediately before the injection because the polymerisation of the resin takes place after a certain time, which depends on the temperature, and renders it useless for injection purposes.

<u>Apparatus</u>/

Apparatus - Filter funnel - diameter 15cm.

Rubber tubing.

Glass cannulas with terminal collars.

Procedure for injection - Lambs from three to four days old which had died on the hill were used for the injection. The lungs were injected "in situ" to prevent the collapse and loss of shape which ensued when they were removed from the thorax. The lambs were placed on their backs and the trachea was dissected out in each by incising the neck along the mid ventral line and cutting through the underlying muscles.

The filter funnel was attached to a cannula by a piece of rubber tubing; the injection mass was poured into the funnel and allowed to fill the rubber tubing and the cannula, before the latter was tied into the trachea; in this way it was possible to prevent air from being forced into the bronchial tree. The filter funnel was held at a level of 24 inches above the lungs.

The injection was continued until the injection mass had set, and the lungs were left "in situ" for a further 24 hours to allow the mass to harden, when they were removed from the thorax, placed in a tank containing a strong solution of sodium sulphide and incubated at 45^{o} C, until the lung tissue had been macerated; the sodium sulphide removed the lung tissue without harming the injection mass.

Finally the cast was washed with a fine jet of water until all the lung tissue had been removed and was then allowed to dry (Plate VI).

C. Serial/

C. <u>Serial sections of the cardiac lobe of the right lung.</u>

The method of sectioning the cardiac lobe of the right lung was based on the technique described by Gough, James and Wentworth (1949) for cutting sections of the entire lung and mounting on paper, but modified to include the injection of the blood vessels and bronchi with a gelatin injection mass so that they could be easily recognised when the sections were mounted.

The heart and lungs were removed from a freshly killed sheep, care being taken to avoid damaging the pulmonary pleura and the pericardium. It was later intended to inject the blood vessels with a gelatin mass, and so these were quickly washed out with warm normal saline solution, as described in the method for the corrosion casts. The lungs were then distended by running into the trachea the following fixative solution:

Liq. formaldehyde	750cc.
Sodium acetate	300cc.
Water	to 7500cc.

The solution was contained in a reservoir which was connected by a piece of rubber tubing to a cork with a central glass tube. Before this cork was tied into the trachea, the solution was allowed to fill the rubber and glass tubes and as much air as possible was expressed from the lungs. The lungs were then placed in a tank containing water and allowed to float freely; at first the reservoir was anchored approximately 1 foot above the lungs and then, as the lungs were filled, the reservoir was gradually raised to a height of 4 feet above the lungs.

When/

When the lungs had been filled, they were removed from the water and placed in a glass tank containing the remainder of the fixative solution; the tank had to be large enough to allow the lungs to float freely without pressure from the sides. It was found that about 2000cc were necessary to distend the lungs and the remainder of the solution was used in the tank. It was not necessary to tie off the trachea after the injection, and the cork with the glass tube was left in position for future use. The lungs were left to fix for a week after which they were removed from the solution and allowed to drain.

At this stage the blood vessels and bronchi were filled with the gelatin injection mass.

Material for Injecting the Blood Vessels.

The injection mass had to be in a colloidal form; (if it is in a state of true solution the mass diffuses through the vessel walls into the surrounding tissues). The pulmonary arteries therefore were injected with a Carmine-Gelatine mass which was prepared as follows: 10cc of distilled water were added to 5grms of unpowdered carmine in a stoppered flask and allowed to stand overnight. Then 200cc of strong ammonia were added and, after shaking, the flask was allowed to stand. After a further shaking, the contents of the flask were filtered twice through glass wool. The filtrate was then poured into a stoppered flask which contained 50 grms powered gelatin and a crystal of thymol, the latter to prevent fungoid growth. The flask was placed in an incubator at 37° C until the gelatin had dissolved; then the stopper was removed and

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the flask left in the incubator until all the trace of ammonia had disappeared. Distilled water was added to make up to the original volume, and after a further night in the incubator, the solution was filtered through glass wool.

The pulmonary veins were injected with Ranvier's Prussian Blue Gelatine mass. This was prepared by adding a 4% solution of gelatine to an aqueous solution of Prussian Blue. About 200cc of the injection mass was prepared.

The bronchi were injected with a 20% solution of gelatine to which had been added sufficient green dye to colour the solution to the required intensity; Monolite Fast Green B.N.S. as supplied by the Imperial Chemical Industries was used for this purpose. It was not found necessary to inject the bronchial tree with a colloidal gelatin injection mass.

Apparatus required for Injection - The apparatus required for the injection was as follows.

Air pump & pressure chamber(Edwards Type IV compressor and vacuum pump).

Mercury manometer.

Pressure bottle.

Water bath in which the pressure bottle was placed.

Tank in which the lungs were floated during the injection.

Rubber tubing.

Glass cannulas.

Injection Procedure - The procedure for the injection of the blood vessels with gelatin was the same as described for their injection with celloidin or vinylite with the following exceptions. The lungs were floated in a tank (D) containing/

containing water kept at a temperature of 60° - 70° C. The gelatin injection mass was heated in a water bath, until it had melted and was in solution, and then it was poured into the pressure bottle. The pressure bottle was kept in a water bath (C) during the injection at a temperature of 60° - 70° C. The arteries were injected under a pressure of 160mm of mercury and the veins under a pressure of 80mm of mercury (Plate VII, fig. 1).

Following the injection of the blood vessels, the bronchial tree was injected by gravity feed; the injection mass was first heated in a water bath until the gelatin had melted and was in solution; then the lungs were floated in hot water at a temperature of 60° - 70° C and were connected to the filter funnel containing the injection mass by a piece of rubber tubing which was attached to the cannula in the trachea. The filter funnel was held about 2 feet above the level of the lungs. After the gelatin injection mass had set in the bronchial tree, the lungs were returned to the fixative solution for a further 2 - 3 days.

Gelatin was used as an injection mass because it did not interfere with the cutting and mounting of the lung sections. The formaldehyde present in the lungs before the injection and the subsequent immersion of the lungs in the fixative solution served to alter the form of the gelatin in the blood vessels and bronchi so that it did not melt during the succeeding stages of the method.

It had been decided to section the cardiac lobe of the right lung and at this stage the cardiac lobe was removed from/

from the rest of the lung. This was carried out by breaking down the connective tissue planes between the diaphragmatic and apical lobes, and cutting through the lobar bronchus and blood vessels at the apex of the lobe. The lobe was then cut into five slices approximately $\frac{3}{4}$" thick; a pencil outline was made of each slice and this was labelled so that it would be possible to orientate the sections after they had been cut. Following this, the slices were placed in a jar of running water for 72 hours to remove the formalin, and then placed in the following solution:

Gelatin	100grms.
Propylene-Phenoxetol	10cc.
Capryl alcohol	5cc.
Distilled water	800cc.

In order to facilitate the penetration of the lung slices by the gelatin, it was necessary to remove the air present in the slices. The lung slices in the above solution were placed in a round glass jar. The jar was then placed in a paraffin wax vacuum embedder which was thermostatically controlled at 40° C, and kept there for one hour. The contents of the glass jar were then removed and put into a covered perspex container, which was placed in an incubator at 37° C for 72 hours.

The lung slices were then placed in the following solution:

Gelatin	200grms.
Propylene-Phenoxetol	10cc.
Distilled water	800cc.

and/

and returned to the incubator at 37° C for 72 hours. They were then incubated for a further 72 hours at 37° C in the following solution:

Gelatin	250grms.
Propylene-Phenoxetol	10cc.
Distilled water	800cc.

Following this, the lung slices were ready to be embedded. Each lung slice was embedded separately using the final gelatin solution. A rectangular perspex mould (A) was made; it had the same surface dimensions as the modified microtome block holder (B), 3.8 inches X 3.4 inches X 1.5 inches, and it had a removeable bottom (Plate VII, fig. 2). About 5cc Liq. formaldehyde were added to 200cc of the gelatin embedding solution; a small quantity of the solution was then poured into the mould to cover the bottom, and the lung slice was placed in the mould with the cutting surface downwards; care was taken to ensure that no air bubbles were trapped under it. The rest of the gelatin solution was then poured over the lung slice and allowed to set.

The block was allowed to cool thoroughly overnight and then it was removed from the mould by pushing out the removeable bottom, to which the block was attached, using the wooden block holder. The perspex bottom was removed and the gelatin block immersed in 10% formalin for about a week to harden. The remaining lung slices were blocked in the same way and the blocks were numbered to avoid confusion when cutting the slices in series.

A Reichert sliding microtome was used for cutting the sections;/

sections; a wooden block holder, surface dimensions 3.8 inches X 3.4 inches was specially made to hold the large blocks (B) (Plate VII, fig. 2).

Before attempting to attach the block to the microtome holder, the surface of the gelatin was roughened by serating it with a wire brush. The block holder was warmed with hot water and some hot 20% gelatin solution was poured on to it. The gelatin block was then placed on the holder with the scratched surface down and held in position by lead weights until it was firmly fixed. It was usually possible to cut the block in one hour's time.

Sections were cut at a thickness of 600 microns, they were cut in series and kept under water until they were mounted. The following solution was used for mounting the sections on paper:

Gelatin	75 grms.
Glycerin	70 cc.
10% Camphor in Meth. Spirits	10 cc.
Distilled water	800 cc.

According to their size from six to nine sections were mounted on a piece of Whatman's No. 1 filter paper cut to quarto size; a large sheet of perspex 2 feet X 3 feet was obtained and some of the warm gelatin solution poured on to an area, the size of the quarto paper, in the top left hand corner; the surplus gelatin was trimmed round the edges of each section, and the sections were then laid in series on the gelatin solution on the perspex and covered with a sheet of filter/

filter paper. By running a rubber roller squeegee lightly over it the surplus gelatin and air bubbles were squeezed out. The perspex sheet was placed on end for 15 - 30 seconds to allow it to drain and then laid flat. This process was repeated until the perspex sheet was filled; it was then allowed to stand until the filter papers were quite dry and could be peeled off the perspex. The sections now appeared mounted on the papers under a glazed surface. These papers were then kept in an envelope to prevent crushing.

When mounting the sections, it was important to make certain that they were all oriented correctly, and it was found that the pencil outlines of the lung slices which had been drawn earlier were of great value.

The sections were examined using a hand lens and a binocular dissecting microscope (Sheets 1 - 14).

Method used to determine the number of subdivisions of the bronchial tree.

The lungs were removed from a freshly killed adult sheep, fixed by inflating them with 10% formalin into the bronchial tree, and subsequent immersion in 10% formalin for 14 days.

The segmental bronchi, which were to be examined for the number of side branches were selected, and were then exposed by cutting along their walls with scissors. The side branches were counted and if, at a division, there was any doubt as to which bronchus should be followed, a probe was passed down each bronchus and the one which led to the furthest tip of the segment was followed.

When/

When the bronchus and its branches became too small for visual examination, the remainder of the segment was cut into a block, with the bronchus in the centre; the size of the block was usually in the region of 2cm X 2cm X 3cm. The block was embedded in paraffin wax and then the sections were cut in series. The sections were 10 microns thick and every seventh section was mounted. This meant that there was only a gap of 60 microns between each section so that there was no chance of a branch being missed.

The sections were stained with Haematoxylin and Eosin and mounted in balsam. They were examined using a dissecting and low power microscope; a note was made of the point where the cartilage plates disappeared so that the bronchial subdivisions could be differentiated from the bronchiolar subdivisions.

Methods used to demonstrate the broncho-pulmonary segments.

A. Air Inflation.

A quick method which was used to delineate the segments was the inflation of the segment with air. For this, lungs which had been removed from freshly killed adult sheep were used; care had to be taken during the removal of the lungs to ensure that the pulmonary pleura was not damaged in any way.

Air pressure was obtained from an Edwards Type IV compressor and vacuum pump, which was connected by rubber tubing to the glass cannula inserted into the segmental bronchus. A long glass cannula which had been sharply tapered at/

at one end was used, the cannula was inserted into the bronchus to be studied and held in position hard against the wall of the bronchus to prevent leakage. An assistant slowly released air under pressure from the pump, when the segment had been inflated sufficiently to produce delineation, but not to break down the alveoli, the air inflow was stopped but the cannula was maintained in position.

This method allowed a quick survey to be made of the extent of the segments. The lungs of five sheep were examined by this method.

B. Gelatin Injection.

A second method which was used to demonstrate the broncho-pulmonary segments was the injection of the segments with coloured gelatin solutions. The gelatin solution entered the alveoli and was seen on the surface of the lung. The lungs of six sheep were studied using this method.

Materials - The injection mass was a 15% solution of gelatin in water. 150 grammes of Gurr's bacteriological gelatin were immersed in a flask containing 1000cc of water. The flask was placed in a water bath and heated until the gelatin had melted and was in solution. The solution was then divided into four lots of 250cc each; these were coloured red, blue, green and yellow and stored in smaller flasks. The colouring agents used were Monolite Fast Scarlet Paste R. N.V.S., Monastral Fast Blue Paste B.V.S., Monolite Fast Green B.N.S. and Monolite Fast Yellow G.N.V.S. as supplied by the Imperial Chemical Industries.

Apparatus - Several glass cannulas of different bores were/

were prepared each with a terminal collar (Plate VII, fig. 3A). The purpose of having cannulas of different sizes was to allow for the different sizes of bronchi; the terminal collar served to prevent the cannula slipping out of the bronchus after it had been tied.

An 8oz metal bladder syringe was used for the injection and it was connected to the cannula by rubber tubing.

Curved suture needles and strong thread were required for ligaturing the bronchi.

Procedure for Injection - The heart and lungs were removed from a freshly killed adult sheep, care was taken during their removal to ensure that the pulmonary pleura was not damaged in any way because this would have resulted in leakage during the injection.

The pulmonary vessels were cut through, and then the heart and aorta were dissected away from the lungs; the oesophagus and mediastinal lymph nodes were also removed by dissection.

The bronchial tree was washed out to remove any mucous etc. by filling the trachea and bronchi with warm water and then allowing them to drain. This was repeated two or three times.

The trachea was incised along the mid-dorsal line as far as its bifurcation into the right and left main bronchi. The segmental bronchi were identified, and the lung tissue surround -ing them was carefully removed by blunt dissection to allow the ligatures to be passed round each bronchus; these had to be as close as possible to the origin of the bronchus, to prevent a branch near the origin becoming occluded with the result/

result that an area of the segment would not be injected. It was important to identify and ligature the bronchi before commencing the injection of the segments, because the injection made subsequent identification very difficult.

Before the injection was started, the lungs were floated in a tank containing cold water; the purpose of this was to enable the surface of the lungs to be viewed easily. The coloured gelatin mass was heated in a water bath to bring it into solution, and the metal syringe was also placed in the water bath to warm it. The syringe was filled with the gelatin solution which was pumped into the rubber tube and cannula before the cannula was inserted into the bronchus; this was done to prevent an excessive amount of air being forced into the segment and appearing under the pleura.

The cannula was inserted into the bronchus and tied by an assistant using the first half of a surgeon's knot. The segment was injected by exerting gentle pressure on the syringe. When the segment had been sufficiently distended, the cannula was withdrawn and the bronchus ligatured by tightening and completing the knot. If an obstinate leak appeared, the lungs were completely immersed in the cold water and if necessary formalin was applied to the leak. This had the effect of coagulating the gelatin.

The broncho-pulmonary segments of the right lung were injected in the following order; cranial and caudal segments of the right apical lobe, the medial followed by the lateral segment of the cardiac lobe, the ventral basal and apical segments of the diaphragmatic lobe, and the dorsal and ventral segments/

segments of the intermediate lobe. The segments of the left lung were injected in the following order; apical and cardiac segments of the apical-cardiac lobe, the ventral basal and apical segments of the diaphragmatic lobe.

It was found that to ligature the deeply placed segmental bronchi required considerable dissection of the lung tissue and consequent leakage during the injection. The procedure for the injection of these inaccessible segments in the right and left lungs was modified. Instead of using a cannula with a collar which was ligatured into the bronchus, a sharply tapered cannula with a greater diameter than the bronchus was used (Plate VII, fig. 3B). The method required that the cannula was held hard against the wall of the bronchus by an assistant during the injection to prevent any of the gelatin solution leaking back.

The gelatin was allowed to harden in the segments already injected, and then the main bronchi were incised along their medial border for a short distance to allow easier access to the remaining bronchi. The lateral basal segment was injected first, but before starting the injection, the entrances to the medial basal segmental bronchus, the subapical segmental bronchus and the dorsal basal segmental bronchus were plugged with cotton wool to prevent any of the gelatin solution which might escape entering these segments. A tapered plug of cotton wool was soaked in formalin ready to be inserted into the lateral basal segmental bronchus when the segment had been injected. The injection was carried out as before and when completed the plug was inserted into the bronchus. The formalin/

formalin coagulated the gelatin in the segmental bronchus and the lung was immersed in cold water to hasten the setting of the gelatin solution.

The subapical and medial basal segments were injected in the same way, and then the dorsal basal segment was injected by ligaturing a cannula into the lobar bronchus after the gelatin had set in the above segments. Following the injection of the segments, the lungs were immersed in a jar containing 10% formalin (Plate VIII).

An alternative method for the injection of the segments with coloured latex solutions was tried out but did not appear to have any advantage over the gelatin method. The method was described by Tobin and Zariquiey (1950) and is based on the theory that, if the residual air is replaced by a gas that is miscible with and absorbed by the injection solution, a complete filling of the segments could be obtained. Carbon dioxide gas was used to replace the air and this was later absorbed by the alkaline latex solution.

C. Marco-resin Casts.

A third method which was used to demonstrate the broncho-pulmonary segments was the fine injection of the bronchial tree using Marco-resin S.B. 26c. The injection mass entered the alveolar ducts and when the lung had been removed by maceration, the broncho-pulmonary segments were separated by deep fissures. The segments were then coloured and the casts were mounted on stands. Seven casts were prepared by this method.

Material - Marco-resin S.B. 26c.

Chalk./

Chalk.

Strong solution of Sodium Sulphide.

Coloured drawing inks.

Marco-resin has been described in the method for the preparation of coarse corrosion casts of the bronchial tree. To prepare fine casts for the demonstration of the segments the injection mass was made up as follows:

500cc	Solution A.
70cc	Solution B.
70cc	Solution C.
8oz	Chalk.

The injection mass had to be prepared just before the injection was due to take place.

Apparatus - Filter funnel - diameter 15cm.

Rubber tubing.

Glass cannulas with terminal collar to fit into the trachea.

Air-spray brush.

Procedure for injection - This was carried out as described for the preparation of coarse corrosion casts. When the cast had been dried, deep fissures appeared along the lines of the intersegmental connective tissue planes and allowed the broncho-pulmonary segments to be identified.

The segments were then coloured by spraying them with coloured drawing inks. A Conograph air-spray brush, manufactured by Connor Patents, Ltd., 2a, Brunswick Street East, Hove, Sussex, was used for this purpose.

When/

When the cast showing the segments was completed, it was mounted and provided a permanent demonstration of the size and extent of the broncho-pulmonary segments (Plate IX).

The Development of the Bronchial Tree.

The development of the lungs of the sheep has been studied by a number of workers. Cadiat (1877) in his paper on the embryology and histology of the lung studied the development of the lung in sheep embryos of 12 - 15mm and upwards, and Bonnet (1891) and Stoss (1892) have described the early development of the lungs in sheep embryos. They were of the opinion that the lungs develop from an unpaired anlage, which is formed, at first, by a longitudinal furrow which separates the head gut into dorsal and ventral portions; the former gives rise to the oesophagus, while the latter gives rise to the respiratory system. The dorsal and ventral portions then separate, and the cranial part of the ventral portion forms the trachea while the lungs develop from the caudal part of the anlage.

Nicolas and Dimitrova (1897) studied the development of the lungs in sheep embryos of 5 - 18mm (about 18 - 27 days), by means of the Born reconstruction method, and the following is taken from their description of the formation of the principal bronchi: in embryos of 5 - 6mm, it can be seen that the stem bronchi do not result from a bifurcation of the first pulmonary bud, but they appear as buds arising from the dorsal part of the lateral aspects of this anlage. Already in a 5mm embryo, it can be seen that these buds are asymmetrical,/

rical, the right being better developed and situated a little behind the left. At first, they lie at right angles to the sac from which they arise and they are enlarged at their termination. In embryos of 7 - 9mm, the two buds, or stem bronchi as they are now, form an inverted T with the trachea.

In embryos of 9mm, the axis of each stem bronchus begins to curve caudally. At the same time, two buds develop symmetrically one on the right, the other on the left, on the cranial wall of the stem bronchi. Each bud grows forward in such a manner that it follows a recurrent course; the one on the left grows more quickly than the one on the right. These are the buds of the first collateral external trunks; eventually the orientation of the buds is modified due to the caudal prolongation and more noticeable bending of the stem bronchi; the right collateral trunk finally runs caudally and ventrally but the left trunk continues to run cranially and laterally.

Also, in the embryos of 9mm, the tracheal bronchus, the eparterial bronchus of Aeby, makes its appearance as an elongated bud projecting from the right side of the trachea. Later it develops at right angles to the trachea and then bends caudally giving off collateral buds.

Collateral bronchi continue to arise in the form of buds from the stem bronchi, one after the other in a cranial to caudal direction, and earlier on the right side than on the left. The difference in the diameter between these collateral bronchi and the parent trunk is always very noticeable and in favour of the latter. Three series of buds arise in this way;/

way; a lateral series, a dorsal series, and a ventral series.

The first two lateral bronchi, which have been mentioned above, appear about the same time. The one of the left side, in embryos of 10 - 11mm, is seen to give off buds which enlarge laterally and later bend ventrally, but the general direction of the bronchus remains as it was in the beginning, that is to say, it is directed cranially.

The first right lateral bronchus is directed caudally but does not give off a branch directed cranially. This particular fact is explained by the development of the tracheal bronchus, which eventually occupies all the lung area in front of the first right lateral bronchus and so prevents the spread in this area.

The first left lateral bronchus is able, on the contrary, to develop freely and finally forms a true hyparterial apical bronchus on the left side.

In embryos of 11mm, three lateral bronchi are found on each side unequally developed, in embryos of 12mm, four lateral bronchi are found on each side unequally developed and in embryos of 18mm, five lateral bronchi are found on each side also unequally developed.

The dorsal bronchi appear more slowly and each arises a little lower on the stem bronchus than the corresponding lateral bronchus.

In embryos of 11mm, one dorsal bronchus is seen on each side, in embryos of 12mm, two dorsal bronchi are seen on each side, and in embryos of 18mm, four dorsal bronchi are seen on each side.

The/

The ventral bronchi are very slow to develop with the exception of the first on the right side, which, on the contrary, develops very quickly. This bronchus appears a short time after the first lateral bronchus and seems to be nearly as long as it, when the second lateral bronchus is still seen as a small swelling. The first ventral bronchus is the cardiac bronchus and it appears ventral and caudal to the first lateral bronchus. In none of the embryos studied did Nicolas and Dimitrova see a similar bronchus on the left side.

The other ventral bronchi form much later; in embryos of 18mm, two ventral bronchi are to be seen on each side (in addition to the cardiac bronchus on the right) and these correspond to the third and fourth lateral bronchi, but are entirely independent from them. Nicolas and Dimitrova came to the following conclusions: that in the sheep, the stem bronchi were lateral dorsal buds from the single pulmonary anlage; that they arose, therefore, from the future trachea in the same way that, later, the collateral bronchi would arise; that the tracheal bronchus was entirely independent from the paired bronchial system and appeared really as a superimposed structure; that the cardiac bronchus was a ventral bronchus and its early appearance gave it particular importance which did not allow it to be considered as an accessory bronchus; and that the asymmetry of the two halves of the bronchial tree was more evident in the sheep than elsewhere and resulted from the two elements, the tracheal bronchus and the cardiac bronchus.

d'Hardiviller/

d'Hardiviller (1897) also studied the development of the principal bronchi in sheep. His paper contains several illustrations, which are reproduced here in Plates X and XI; unfortunately, no indication is given as to the age of the embryos which have been studied. His findings with regard to the development of the main collateral bronchi agree, for the most part, with those of Nicolas and Dimitrova; his nomenclature differs however; in the right lung, he calls the first lateral bronchus of Nicolas and Dimitrova, the middle lobar bronchus, and the second, third and fourth lateral bronchi he names the first, second and third external bronchi of the inferior lobe. On the left side, d'Hardiviller calls the first lateral bronchus, the superior lobar bronchus. In both lungs the ventral bronchi of Nicolas and Dimitrova are termed the accessory anterior bronchi.

d'Hardiviller has observed about the development of the right cardiac lobar bronchus (Ay) that it arises opposite to the middle lobar bronchus (AB) by an anterio-internal bud from the stem bronchus, that is to say by collateral branching. At this stage it is independent of (AB) but soon it appears to be attached to it by an epithelial line. In any case in Plate X, figure 5, it lies at the base of (AB) and in the stage of Plate X, figure 6, it is obliquely attached to (AB). He finds that the bronchus (Ay) arises on the stem bronchus and moves on to (AB). He is of the opinion that the absence of the first ventral or cardiac lobar bronchus on the left side is due to the fact that it has migrated on to the first lateral bronchus to constitute the left cardiac bronchus/

bronchus of Hasse.

d'Hardiviller goes on to describe the early branchings of the main collateral bronchi; he found that the tracheal bronchus (Aa) divides by unequal dichotomy into two branches (Aa1) and (Aa2) (Plate X, fig. 6), and gives off new branches by division at the terminal extremity and by lateral budding (Plate X, figs. 8 & 9). In the right lung, the bronchus of the middle lobe (AB), and the external bronchi (A1, A2 & A3) of the inferior lobe, give rise to new branches by unequal dichotomy and by lateral branching (Plate X, figs. 8 & 9 and Plate XI, fig. 1).

d'Hardiviller's description is that the dorsal or posterior bronchi (Ad1, Ad2 & Ad3) appear as successive buds on the inner, dorsal internal, side of the axial stem bronchus. They are directed caudally and towards the internal part of the lung so that one is able to call them dorsal internal. The first of these posterior bronchi (Ad1) is placed dorsally on the axis between the first and second external bronchi of the lower lobe. There is no dorsal bronchus on the right side between the middle lobe bronchus and the first external bronchus of the lower lobe. The other two dorsal bronchi are placed as follows; the second is between the second and third external, and the third is superior to the third external. The accessory anterior bronchi are at the stage of Plate XI figure 1, numbered two (A3a1 & A4a1). Arising independently from the extremity of the stem bronchus, they are situated the first above, the second below the origin of the third external.

His/

His description of the left lung is that the bronchus to the superior lobe (BB) develops rapidly to end, anteriorly, as a hollow sphere (Plate X, fig. 5) and finally it gives rise to an apical bronchus (BB) by unequal dichotomy (Plate X, fig. 7). The mother bronchus and the apical bronchus continue to give rise to branches by the division of their extremities (Plate XI, fig. 1). The external bronchi of the inferior lobe (B1, B2 & B3) arise by lateral branching, and they increase in size from these buds by lateral branching and also by dichotomy. The dorsal or posterior bronchi (Bd1, Bd2, Bd3 & Bd4) arise in the form of dorsal internal buds from the stem bronchus. The first lies between the bronchus to the superior lobe and the first external bronchus of the inferior lobe. He questions whether this may not be the homologue of the right eparterial, tracheal, bronchus. The second, third and fourth dorsal are situated below the points of attachment of the first, second and third external. At the stage of Plate XI, figure 1, there exists only one anterior accessory bronchus (B2a1). Having arisen by lateral branching it is situated near the axial stem bronchus on the surface of the second external.

d'Hardiviller was of the opinion that the principal bronchi are formed by lateral branching and that the principal bronchi give off secondary bronchi which arise as lateral buds (definite collateral) and by dichotomy (terminal) equal and unequal.

Cadiat (1877) and Stieda (1878) were also of the opinion that the growth process occurs as lateral out-growths from the/

the walls of the bronchi.

Flint (1906) has given a very detailed description of the development of the lungs in the pig. The bronchial tree in the pig is very similar to that of the sheep and it is interesting and helpful to record the findings of Flint in regard to the early development of the bronchial tree.

Flint is of the opinion that the pulmonary anlage in the pig is unpaired and asymmetrical, being produced by a division of the head gut into dorsal and ventral portions, the dorsal portion forming the oesophagus and the ventral portion the respiratory system.

In embryos of 4.5mm, the stem bronchi form as lateral outgrowths from the caudal extremity of the pulmonary anlage; these buds are asymmetrical, the right growing laterally and caudally, and the left growing laterally.

In embryos of 5mm, the tips of the stem bronchi dilate and begin to bend dorsally towards and around the oesophagus, and they still maintain their asymmetrical appearance (Plate XII, figs. 1 & 2).

In embryos of 7.5mm, the formation of the bronchi begins. Flint has divided then into four series, according to the topography of their origin, lateral, dorsal, ventral and medial. Generally they are produced slightly earlier on the right side than on the left. The first lateral (L1), the eparterial or tracheal bronchus of Nicolas and Dimitrova, and d'Hardiviller, arises as an unpaired lateral outgrowth from the right side of the trachea (T) just above the roots of the stem bronchi (Plate XII, figs. 3 & 4).

In/

In embryos of 8.5mm, the lateral bronchi (L2) appear on the stem bronchi (s & d) one on each side (Plate XII, figs. 5 & 6) ; in embryos of 12mm, two lateral bronchi (L2 & L3) are evident on each side, and in embryos of 13.5mm, three lateral bronchi (L2, L3 & L4) can be seen on each side (Plate XII, figs. 11 & 12). In embryos of 15mm, there are four lateral bronchi (L2, L3, L4 & L5) on each side (Plate XIII, figs. 1 & 2).

The dorsal series of bronchi originate like the lateral group as outgrowths from the stem bronchi, and are usually paired. They alternate with the lateral bronchi and are independent productions of the stem bronchi. In embryos of 10mm, the first dorsal bronchus (D2) is to be seen on the right side (Plate XII, fig. 8), and in those of 12mm, on both the right and left sides (Plate XII, fig. 10). In embryos of 13.5mm, there are two dorsal bronchi (D2 & D3) on each side and in embryos of 15mm, there are three dorsal bronchi (D2, D3 & D4) on each side (Plate XIII, fig. 2).

The ventral bronchi originate as outgrowths from the ventral surface of the stem bronchi, and are independent productions from the stem bronchi. In the pig, as in the sheep, there is no sign of the first ventral bronchus on the left side; on the right side the first ventral (V2) is produced as an evagination of the wall of the stem bronchus first appearing in the embryo of 10mm (Plate XII, fig. 7). In the embryo of 13.5mm, the second ventral bronchi (V3) have appeared, one on the left side and one on the right, between the second lateral (L3) and the second dorsal bronchi (D3) arising/

arising from the stem bronchus (Plate XII, figs. 11 & 12). In the embryo of 15mm, the third ventral bronchi (V4) have arisen and lie between the third (L4) and fourth (L5) lateral bronchi which arise from the stem bronchus (Plate XIII, fig. 1).

Similarly, the medial bronchi (M) are produced by medial outgrowths from the stem bronchi; they are not formed on the dorsal bronchi and then transferred to the stem bronchi; they rarely occur cranial to the level of the third lateral bronchus (L4) arising from the stem bronchus, and they are extremely irregular in their arrangement. They are first seen in embryos of 13.5 - 15mm (Plate XIII, fig. 2).

The further growth of the bronchial tree has also been studied by Flint; in an embryo of 13.5mm, the tracheal bronchus (L1) is seen to have divided into two almost equal branches, one passing caudally and dorsally and the other passing cranially and laterally (Plate XII, figs. 11 & 12). On the right side, the first lateral bronchus (L2) which arises from the stem bronchus runs in a lateral and cranial direction has divided almost equally into two dichotomous branches, the continuation which runs in a ventral direction, and a lateral branch which is directed dorsally and caudally (Plate XII, figs. 11 & 12). On the left side, the first lateral bronchus (L2) arising from the stem bronchus runs in a lateral and dorsal direction; it has also divided into two branches, one which runs in a dorsal and cranial direction, and another which runs in a ventral and lateral direction (Plate XII, figs. 11 & 12); the former forms the apical bronchus.

The/

The growth of the main series of bronchi is monopodial in character while the subsequent division of branches may occur either by monopody, or by dichotomy which may be equal or unequal in character; the type of division depends on the space in which the bronchi have to divide.

It can be seen that the development of the lungs in the sheep and pig follows similar lines, and although variations would seem to occur in regard to the age at which certain bronchi appear and the position which they have on the stem bronchus, the general scheme is the same. As the growth of the lung continues, it is likely that, as Flint has suggested, each lung will be influenced by the space in which it has to develop, the lateral bronchi, for example, being forced to grow in a ventral direction as they approach the chest wall.

It will perhaps clarify the development of the bronchial tree in the sheep if at this stage a summary is given, introducing the nomenclature which will be used in the description of the adult bronchial tree.

Bonnet (1891) and Stoss (1892) would appear to have been correct when they stated that the lungs develop from an unpaired pulmonary anlage which has been formed by a splitting of the head gut into dorsal and ventral portions, and it is likely that this anlage becomes asymmetrical, as described by Flint (1906) in the pig, because both Nicolas and Dimitrova (1897), and d'Hardiviller (1897) have described how the stem bronchi, (main bronchi), develop asymmetrically from the anlage. The right main bronchus grows in a caudal lateral direction, while the left main bronchus grows in a lateral direction/.

direction. They both incline dorsally with the result that the oesophagus lies between them.

From the work of Nicolas and Dimitrova, and d'Hardiviller on the sheep, Flint on the pig and Miller (1947) on the human it would appear that the growth of the main series of bronchi is monopodial in character, that is to say, without a definite division of the end bud. However, new elements may be formed from the main bronchus at some distance from its terminus, for example the dorsal and ventral bronchi. The process of formation is successive for any series of bronchi.

The tracheal bronchus, right apical lobar bronchus, first appears to develop in an embryo of 9mm; growing at first in a lateral direction and then bending caudally, it divides dichotomously into two bronchi which will form the cranial and caudal broncho-pulmonary segmental bronchi in the adult lung.

The first lateral bronchus from the right main bronchus will now be known as the right cardiac lobar bronchus, and the first lateral bronchus from the left main bronchus as the left apical-cardiac lobar bronchus. They appear first as lateral outgrowths from the main bronchi in embryos of 9mm, the right cardiac bronchus slightly ahead of the left. The right cardiac lobar bronchus runs in a lateral and caudal direction and divides dichotomously into two bronchi, the continuation or ventral bronchus which will form the medial segmental bronchus, and the lateral or dorsal bronchus which will form the lateral segmental bronchus in the adult. The apical-cardiac lobar bronchus grows in a lateral direction and/

and divides into two branches, the apical bronchus, and the mother bronchus; the former grows in a cranial direction, and in the adult, will form the apical segmental bronchus of the apical-cardiac lobe, while the mother bronchus continues in a lateral direction, and in the adult, will form the cardiac segmental bronchus of the apical-cardiac lobe.

The first ventral bronchus, right intermediate lobar bronchus, arises from the ventral medial aspect of the right main bronchus in embryos of approximately 10mm. It is unlikely that this bronchus migrates on to the right cardiac lobar bronchus, as has been suggested by d'Hardiviller. Having studied the bronchial tree in the adult lung, the writer is of the opinion that the right cardiac lobar bronchus and the right intermediate bronchus have a common origin from the main bronchus, and a more probable explanation is that the right intermediate lobar bronchus arises from the main bronchus close to the right cardiac bronchus, and during their development, both bronchi enlarge their openings and eventually these conjoin. According to the studies of Nicolas and Dimitrova, and of d'Hardiviller a homologous bronchus does not develop on the left side, and the writer has never seen a trace of such a bronchus in the adult lung. It seems unlikely that on the left side this bronchus has migrated on to the first lateral bronchus to form the left cardiac bronchus of Hasse, that is, the cardiac segmental bronchus of the apical-cardiac lobe, as has been postulated by d'Hardiviller. The writer feels that a more likely explanation is to be found in the opinion, expressed by Flint, that a bronchus may/

may be suppressed should there be insufficient space available for its development, and that the adaption on the part of the lungs to their environment is to be expected, because, compared with the heart and liver, they are late accessories to the animal economy and are of no known use to the organism during the period of gestation.

In embryos of approximately 10mm, the second lateral bronchi, ventral basal segmental bronchi of the diaphragmatic lobe, arise from the continuations of the right and left main bronchi which are known as the diaphragmatic lobar bronchi, while in embryos of 11mm, the third lateral bronchi, lateral basal segmental bronchi of the diaphragmatic lobe appear as buds on the lateral aspect of the diaphragmatic lobar bronchi. Generally the bronchi on the right side make their appearance a little before those on the left side. These bronchi would seem to give rise to new branches by collateral branching and by dichotomy.

The dorsal bronchi appear later than the corresponding lateral bronchus; according to the study made of the bronchial tree in the adult, their position on the diaphragmatic lobar bronchus in relation to the lateral bronchi is variable. d'Hardiviller describes the buds of the dorsal bronchi as arising from the dorsal-internal side of the axial bronchus, and as growing backwards and towards the internal part of the lung. This is not in accordance with the findings in the adult lung, but may perhaps be accounted for by the fact that when the lateral bronchi extend to the chest wall and are forced to grow ventrally, there is a tendency for each lung to/

to be rotated about its longitudinal axis in a lateral direction; the result is that, in the adult lung, the dorsal bronchi appear on the dorsal aspect of the main bronchus and seem to grow in a caudal direction.

The first dorsal bronchus of each side, the apical segmental bronchus of the diaphragmatic lobe, appears in embryos of 11mm, and the second dorsal bronchus of each side, the subapical segmental bronchus of the diaphragmatic lobe, in embryos of 12mm.

The second ventral bronchi of each side develop later and first appear in embryos of approximately 13mm. The position at which each arises from the diaphragmatic lobar bronchus, is discussed in the description of the bronchial tree, in which these bronchi are known as the medial basal segmental bronchi of the diaphragmatic lobe.

Caudal to the point at which it has given off the ventral basal, lateral basal, apical, subapical and medial basal segmental bronchi, the diaphragmatic lobar bronchus is known as the dorsal basal segmental bronchus of the diaphragmatic lobe, and the lateral, dorsal, ventral and medial branches are described as subsegmental bronchi of the dorsal basal segment; these make their appearance in embryos of 18mm.

The further growth of the bronchial tree would appear to be by monopody (collateral branching) or by dichotomy.

The Development of the Pulmonary Arteries and the Pulmonary Veins.

As far as is known, the development of the pulmonary arteries and the pulmonary veins has not been studied in the sheep./

sheep. Flint (1906), however, has made a study of the development of these vessels in the pig, and as the end result is very similar in the pig and sheep, perhaps it may be permissible to assume that the development of these vessels in the sheep follows the same stages as in the pig. In this recording of Flint's findings, the nomenclature used in the description of the adult sheep has been substituted for that used by Flint.

According to Flint, the pulmonary arteries in the pig, as in other mammals, originate symmetrically from the sixth pulmonary arch, and in embryos of 5mm, may be seen running in a caudal direction. In embryos of 6mm, they may be seen running parallel until they diverge and become lost in the dorsal aspect of the right and left bronchi in the capillary plexus surrounding the primitive lung sac (Plate XII, figs. 1 & 2). Because of the asymmetrical arrangement of the right and left main bronchi the left artery is forced to bend more sharply downwards than the right artery.

At this stage, the pulmonary vein may be seen growing from the still undivided atrium in a dorsal direction towards the lung anlage; it is connected to the capillary network about the head-gut and lung anlage, and in this way establishes a venous outflow on the ventral side of the latter (Plate XII, fig. 3). The ventral position of the venous outflow encourages the capillaries on the dorsal aspect to form arteries, and the ventral growth of the respiratory apparatus after its separation from the oesophagus makes it easier for these arteries to form on the dorsal surface.

In/

In an embryo of 7.5mm, the right artery is still slightly more ventral in position than the left and is nearer the median plane. Dorsal to the right artery the right apical lobar bronchus (L1) is appearing as a bud on the lateral wall of the trachea. At this stage, the pulmonary vein is seen to have two small tributaries, a cranial and caudal, and these are in communication with dilated capillaries in the region of the lung sacs (Plate XII, figs. 3 & 4).

In an embryo of 8.5mm, the right and left pulmonary veins have formed and these may be seen draining into a common trunk (V) which now opens into the left atrium (Plate XII, fig. 5).

In an embryo of 10mm, the pulmonary arteries still have the same relationship to the trachea; developing caudally they lie on the dorsal lateral aspect of the main bronchi and give off branches to the capillary plexus which surrounds the bronchial tree. The right and left pulmonary veins lie on the ventral medial aspect of the main bronchi, originating from the capillary network. At this stage, the basic relationship of artery, bronchus and vein, which generally speaking exists throughout the adult lung, has already been established (Plate XII, figs. 7 & 8).

In an embryo of 12mm, it can be seen that branches are being given off from the right and left arteries. These are formed in the capillary plexus on the dorsal aspect of the right cardiac and left apical-cardiac bronchi respectively (Plate XII, fig. 10). In an embryo of 13.5mm, the artery to the right apical lobar bronchus (L1) may be seen developing from/

from the right pulmonary artery along the ventral aspect of the bronchus; a branch may also be seen arising from the right pulmonary artery, and passing caudal to the root of the right cardiac lobar bronchus (L2) in a ventral direction, it reaches the lateral ventral aspect of the right intermediate lobar bronchus (V2) (Plate XII, fig. 11). In the sheep, it may be assumed that the artery to the right intermediate lobar bronchus arises from the right artery on a level with, or cranial to, the artery accompanying the right cardiac lobar bronchus, and passing in a ventral direction cranial to the root of the cardiac lobar bronchus, it reaches the lateral ventral aspect of the right intermediate lobar bronchus: this is the position and course of this artery in every adult lung which has been studied, and the difference from the artery in the pig may be explained by the fact that the right intermediate lobar bronchus arises from the main bronchus at a more caudal point in the pig than in the sheep.

In an embryo of 13.5mm, a branch from the right apical lobar bronchus (L1) may be seen passing down to the common pulmonary vein. It lies ventral to the artery to the right apical lobe as it does in the adult pig's lung. The same relationship is found in the adult sheep's lung. Veins may also be seen forming on the ventral aspect of the right cardiac (L2) and left apical-cardiac (L2) lobar bronchi and on the dorsal medial aspect of the right intermediate lobar bronchus (V2), these veins open into the right and left pulmonary veins respectively (Plate XII, fig. 11). Flint has noticed that, in the pig embryos at this stage, the pulmonary veins are frequently/

frequently duplicated.

In an embryo of 15mm, the artery to the right apical lobe may be seen dividing into branches which correspond to the branches of the lobar bronchus (L1). At this stage the pulmonary arteries can be seen lying on the dorsal lateral aspect of the diaphragmatic lobar bronchi, giving off branches to the ventral basal (L3), lateral basal (L4) and apical (D2) segmental bronchi; the arteries to the lateral bronchi lie on the dorsal aspect of the bronchi and the arteries to the apical bronchi lie on the lateral aspect (Plate XIII, fig. 2).

Venous tributaries, which arise on the caudal ventral aspect of the ventral basal (L3) and lateral basal (L4) segmental bronchi and pass ventral to the diaphragmatic lobar bronchi, enter the right and left pulmonary veins (Plate XIII, fig. 1). The vein accompanying the right intermediate lobar bronchus (V2) enters the right pulmonary vein at the base of the ventral basal bronchus (L3), but from its position in the adult lung, it may be assumed that, in the sheep, it will enter the right pulmonary vein nearer to the common pulmonary vein.

The right and left pulmonary veins form the common pulmonary vein just ventral to the bifurcation of the trachea.

In an embryo of 18.5mm, all the arteries are developing and some are starting to branch. Just distal to the level at which the ventral basal bronchi (L3) arise from the diaphragmatic lobar bronchi, the right and left pulmonary arteries give off arteries which run in a ventral direction over the/

The right and left pulmonary veins lie on the ventral medial aspect of the diaphragmatic lobar bronchi. Each vein receives, as tributaries, veins from the lateral bronchi which lie on the caudal ventral aspect of the bronchi and join the pulmonary veins by passing ventral to the diaphragmatic lobar bronchus and dorsal to the ventral bronchi (Plate XIII, fig. 3). Veins from the dorsal bronchi lie on the medial aspect of the bronchi and pass in a ventral direction over the medial aspect of the diaphragmatic lobar bronchus to enter the pulmonary veins, and veins from the ventral bronchi lie on the medial aspect of the bronchi and enter the pulmonary veins.

The veins from the right apical and right cardiac lobes enter the common pulmonary vein by a common trunk, and the vein from the left apical-cardiac lobe enters the common vein on the oppósite side (Plate XIII, fig. 3).

As the embryo increases in size, the heart and great vessels gradually descend until they reach their final position at birth.

To summarise, in the pig the pulmonary arteries first appear in an embryo of 5mm as right and left arteries which run in a caudal direction from the sixth aortic arch. In an embryo of 10mm, the pulmonary arteries may be seen lying on the dorsal lateral aspect of the right and left main bronchi. In an embryo of 12mm, the arteries start to give off branches which will accompany the lobar bronchi, while in an embryo of 15mm, the right and left pulmonary arteries may be seen on the dorsal lateral aspect of the diaphragmatic lobar bronchi and give off branches to the segmental bronchi. In an embryo of 18mm,/

18mm, the arteries to the lobes and segments have been formed and occupy the positions in relation to the bronchi which they have in the adult.

The pulmonary veins are to be seen developing ventral to the lung anlage, as a dorsal growth from the atrium, in an embryo of 6mm. In an embry of 8.5mm, the right and left pulmonary veins can be seen draining into a common trunk which opens into the left atrium, and in an embryo of 10mm, the pulmonary veins can be seen lying on the ventral medial aspect of the main bronchi. In an embryo of 13.5mm, the veins which drain the lobes are forming, and in one of 18mm, the veins which drain the segments have been formed and the veins are related to the bronchi as they are in the adult.

In the sheep,it seems likely that the pulmonary vessels will have a similar development to those innthe pig, with the exception that (a) the artery to the right intermediate lobe will arise from the right pulmonary artery on a level cranial to the artery to the right cardiac lobe, and will pass in a ventral direction cranial to the root of the cardiac lobar bronchus, (b) the vein draining the intermediate lobe will enter the right pulmonary vein close to the common pulmonary vein, because in the sheep the right intermediate lobar bronchus and the right cardiac lobar bronchus arise from a common opening in the right main bronchus, whereas in the pig, the right intermediate lobar bronchus arises caudal to the right cardiac lobar bronchus.

General Description of the Lungs in the Sheep.

The lungs are paired right and left respiratory organs which/

which occupy a large part of the thoracic cavity. They crepitate when pressed and float in water on account of the large volume of air which they contain. They are pink in colour and are soft, spongy, and elastic. The right lung is much larger than the left.

Each lung has the form of a flattened cone, presenting for description, a base, an apex, two surfaces and two borders.

The base (b) is oval in outline and its surface is concave; it lies in apposition to the thoracic surface of the diaphragm and is bounded by the basal border (bb). This fits into the sinus phrenico-costalis which lies between the diaphragm and the lateral thoracic wall. (Plate XVI & XVII).

The apex forms the cranial part of the lung. The apex of the right lung is much larger than that in the left and occupies most of the cranial part of the thoracic cavity; lying cranial to the pericardium and ventral to the trachea and great vessels, it pushes the mediastinum over to the left side against the thoracic wall. On its cranial aspect, it presents two grooves for the internal thoracic vessels. In the left lung, the apex is small and pointed and it extends as far forward as the second rib lying lateral to the trachea and oesophagus. (Plate XIV & XV).

The parietal or costal surface is convex and it lies against the inner surface of the lateral thoracic wall.

The visceral or mediastinal surface is much less extensive than the lateral surface and it is marked by the structures contained within the mediastinum. Cranially, it is deeply concave/

concave forming a large cavity, the cardiac impression (ci), for the heart and pericardium. In the caudal part of the mediastinal surface, there is a hilus (h) of the lung where the bronchus, blood vessels and nerves enter and leave the lung, and dorsal to the hilus, there is a groove (o) for the oesophagus (Plate XVI & XVII). On the left lung, there is a curved groove (aa) for the aortic arch,and this is continuous with a horizontal groove (a) which lies above the oesophageal groove and contains the dorsal aorta (Plate XVII). On the right lung, there is a curved groove in front of the hilus (h) which contains the vena azygos and a horizontal groove (a) above the oesophageal groove which contains the dorsal aorta (Plate XVI). On the right lung cranial to the hilus (h) and above the cardiac impression, there are grooves for the trachea (T), the brachio-cephalic trunk, the cranial vena cava and the costo-cervical trunk; caudal to the hilus, the intermediate lobe (I) is attached (Plate XVI).

The dorsal or vertebral border (db) is thick and rounded, it lies in the groove which is formed between the bodies of the thoracic vertebrae and the angles of the ribs (Plate XIV & XV).

The ventral border is thin and lies between the mediastinum and the ventral part of the sternal ribs; on a level with the heart it presents the cardiac notch (cn). In the left lung the cardiac notch (cn) is extensive and allows the greater part of the pericardium (P) to lie in contact with the lateral wall of the thorax (Plate XV); in the right lung it is small and only allows the pericardium (P) to contact the

lateral/

lateral thoracic wall in the region of the fourth and fifth ribs (Plate XIV).

The root of each lung is composed of the following structures which enter or leave the lungs at the hilus (h):-

Main bronchus (B).

Pulmonary artery (PA).

Pulmonary veins (PV).

Bronchial artery.

Pulmonary nerves.

Pulmonary lymph vessels.

(Plate XVI & XVII).

Characteristically, the lungs are divided into lobes by deep fissures which extend from the ventral border towards the hilus. A pulmonary lobe may be defined as a large area of pulmonary tissue which is ventilated by a large bronchus arising from either a main bronchus or from the trachea; it is separated from neighbouring lobes by interlobar fissures which may be continued by connective tissue planes, and it is independent with regard to its ventilation, arterial supply and venous drainage.

Sisson and Grossman (1953) and Ellenberger & Baum (1932) describe the left lung as being divided into three lobes, an apical, a cardiac and a diaphragmatic, and the right lung as being divided into four or five lobes, an apical, which is sometimes further divided into a cranial and a caudal lobe, a cardiac, a diaphragmatic and an intermediate lobe. Chauveau (1890) on the other hand describes the left lung as consisting of two lobes, he states that "La forme d'ensemble des poumons

des/

des Ruminants ne diffère point de celle qu'on observe chez le Cheval; on remarquera cependant que le gauche est divisé en deux lobes, et que le droit en présente quatre, dont un antérieur se recourbe en avant du coeur". Paul Martin (1904) is of the opinion that sometimes in the left lung the cardiac lobe is joined to the diaphragmatic lobe and that in these cases there are only two lobes in the left lung.

d'Hardiviller (1897) mentions that the left lung consists of two lobes and that the right lung consists of four lobes, and more recently Bressou and Vladutin (1939) are of the opinion that there are two lobes in the left lung, an anterior and a posterior, and four lobes in the right lung an anterior, a middle, a posterior and an azygos lobe.

In the present study, the left lung is considered to consist of two lobes, an apical-cardiac (AC) and a diaphragmatic (D) (Plate XV), and the right lung to consist of four lobes, an apical (A), a cardiac (C), an intermediate (I) and a diaphragmatic (D) (Plate XIV & XVI). This opinion was formed following the study of the bronchial tree and having regard to the definition of a lobe.

In the left lung, the fissure (F1) separating the diaphragmatic lobe (D) from the apical-cardiac lobe (AC) lies opposite to the fifth and sixth ribs, and arising from the ventral border it runs in a dorsal and cranial direction. The diaphragmatic lobe is in the form of a three-sided pyramid with its base resting on the diaphragm. The apical-cardiac lobe presents a narrow caudal cardiac part (ACc) which is triangular in cross section, and a cranial and dorsal apical part/

part (ACa) which is small and pointed; these two parts are incompletely separated by the cardiac notch (Plate XV).

In the right lung, the fissure (f1) between the diaphragm -atic (D) and cardiac (C) lobes lies opposite to the fifth and sixth ribs, it also arises from the ventral border and passes in a dorsal and cranial direction. The diaphragmatic lobe is in the form of a three-sided pyramid, and the cardiac lobe is tongue-shaped and quadrilateral in cross section. The fissure (f2) between the cardiac and apical (A) lobes lies on a level with the fourth and fifth ribs, and it runs in a dorsal and caudal direction from the cardiac notch (Plate XIV). The apical lobe (A) consists of two distinct parts, a cranial (Acr) and a caudal (Aca), and these are incompletely separated from each other by an indentation in the ventral border which is part of the cardiac notch (cn). The cranial part (Acr) is much larger and occupies the cranial part of the thoracic cavity; it lies cranial to the pericardium (P) and extends over to the left of the median plane (Plate XIV & XV). The caudal part (Aca) is much smaller and is triangular in outline with the apex directed ventrally. The cardiac notch (cn) is formed by the caudal border of the cranial part of the apical lobe and the cranial borders of the caudal part of the apical lobe and the cardiac lobe (Plate XIV). The intermediate lobe (I) is cone shaped with a concave base which is caudal and vent -ral in position and rests on the diaphragm (Plate XVI). The intermediate lobe is separated from the mediastinal surface of the diaphragmatic lobe by a longitudinal and almost vertical fissure; its apex is directed towards the hilus of the lung.

In/

In the dorsal part of its lateral aspect it presents a groove for the caudal vena cava and the right phrenic nerve.

The air is conducted from the larynx by the trachea (T); this tube, which is about 25cm long and about 2cm wide, is kept patent by approximately fifty incomplete cartilaginous rings. It lies median in position until near its termination when it is pushed to the right of the midline by the aortic arch. On a level with the third rib the trachea gives off a bronchus from its right ventral lateral aspect; this bronchus ventilates the right apical lobe and is known as the right apical lobar bronchus (RAL) (Plate XVI). On a level with the fifth rib, the trachea bifurcates into the right and left main bronchi which ventilate the right lung, with the exception of the right apical lobe, and the left lung respectively.

Approximately 1.5cm below the bifurcation of the trachea, two bronchi arise from a common opening in the ventral lateral aspect of the right main bronchus. One bronchus runs in a ventral lateral direction to ventilate the cardiac lobe, the other bronchus runs in a ventral medial and caudal direction to ventilate the intermediate lobe. The continuation of the right main bronchus beyond this point ventilates the diaphragmatic lobe and is known as the right diaphragmatic lobar bronchus.

The left main bronchus gives off a bronchus from its ventral lateral aspect approximately 1.6cm from the bifurcation of the trachea; this bronchus ventilates the apical-cardiac lobe of the left lung and is known as the apical-cardiac lobar bronchus. The continuation of the left main bronchus

beyond/

beyond this point ventilates the diaphragmatic lobe and is known as the left diaphragmatic lobar bronchus.

Each lobar bronchus gives off one or more large bronchi; these bronchi ventilate relatively large independent areas of pulmonary tissue within the lobe which are known as broncho-pulmonary segments and therefore they are termed segmental bronchi. Lying between the segments there are planes of connective tissue, and by breaking down these planes it is possible to separate the segments.

The segmental bronchi, in turn, give off bronchi which ventilate relatively large areas of pulmonary tissue within a segment, referred to as "subsegments", and therefore these ventilating bronchi are termed subsegmental bronchi. The subsegments are separated from one another by planes of connective tissue.

The divisions of the bronchi continue until the diameter is in the region of between 0.8mm and 0.9mm when the cartilage plates are lost. When the cartilage plates are lost the conducting tube is known as a terminal bronchiole; the terminal bronchioles subdivide several times and eventually give rise to respiratory bronchioles which are characterised by the presence of alveolar openings along the walls. According to Miller (1947) the area ventilated by a respiratory bronchiole and its divisions is known as a pulmonary lobule, and this is the unit of lung structure. This differs from the view expressed by Sisson & Grossman (1953) who state that: "A pulmonary lobule, the unit of lung structure, is made up of a lobular bronchiole with its branches and their air cells, blood and lymph/

lymph vessels and nerves". The lobular bronchioles are earlier described as entering a lobule and branching within it to form respiratory bronchioles. The lobular bronchioles of Sisson & Grossman would seem to be analogous to the terminal bronchioles of Miller. The exchange of gases does not take place until the air has reached the respiratory bronchioles, therefore, from the trachea to the respiratory bronchioles, the bronchial tree is merely conductory in function, while the true respiratory part of the lungs starts at the respiratory bronchioles and extends through the alveolar ducts to the atria, air sacs and air cells.

<u>The number of subdivisions of the bronchial tree.</u>

A study was carried out in the sheep to determine the number of subdivisions, or generations, of the bronchial tree between the segmental bronchi, which are termed the first generation, and the respiratory bronchioles which ventilate the pulmonary lobule. This followed the lines of a similar study carried out in the human lung by Hayward and Reid (1952). The bronchial pathways selected were the cardiac segment of the apical-cardiac lobe of the left lung, the lateral basal segment and the medial subsegment of the ventral basal segment of the right lung. Each pathway was followed to the furthest extent of the segment or subsegment. In the cardiac segment, there were sixteen bronchial generations and sixteen bronchiolar generations; in the lateral basal segment, there were seventeen bronchial generations and fifteen bronchiolar generations, and in the medial subsegment there were seventeen bronchial generations and fourteen bronchiolar generations.

These/

These findings suggest that there may be more subdivisions of the bronchial tree in the sheep than in the human; Hayward and Reid obtained a maximum of twenty - twentyfive generations, and of these ten - fifteen were bronchiolar, in examinations of the posterior basal segment in a series of twenty specimens.

Variations in the pulmonary lobation.

In this study, a survey was carried out on one hundred and fifty lungs to determine the size and form of the lobes; it was revealed that variations do occur and that these are very marked in some cases. In the majority of the lungs examined, the lobation corresponded to the description given earlier, although slight variations in the size and depth of the interlobar fissures were noted. In a few of the lungs, however, well marked variations were found to occur. In the right lung the variations will be described lobe by lobe.

The right apical lobe was always divided into cranial and caudal parts, but the extent and the depth of the cardiac notch between the parts was found to vary. In some lungs, the notch was poorly defined (Plate XVIII, fig. 1), in others it was continued by a fissure which extended almost to the point at which the lobar bronchus divided into cranial and caudal bronchi (Plate XVIII, fig. 2). When the notch was deep the cranial and caudal parts of the right apical lobe were very distinct and it was usual to find that the caudal border of the cranial part overlapped the cranial border of the caudal part, that is to say, it lay lateral to the caudal part; in some lungs, however, the position was reversed and the cranial part lay medial to the caudal part.

The

The fissure separating the caudal part of the right apical lobe from the right cardiac lobe was also found to vary in its length and depth; in some lungs the fissure extended to with -in 3 - 4cms of the dorsal border of the lung (Plate XVIII, fig. 3), while in other lungs it existed only as a small fissure extending a short distance from the free margin of the lung (Plate XVIII, fig. 4).

In the majority of lungs, there was no external demarcation on the dorsal aspect of the right lung between the caudal dorsal part of the apical lobe and the cranial dorsal part of the diaphragmatic lobe, however, in 3% of the lungs examined, a break could be seen in the external surface and this marked the connective tissue plane between the above lobes of the lung (Plate XIX, fig. 1).

There was also a variation in the length and depth of the fissure between the right cardiac lobe and the right diaphragmatic lobe. Usually this fissure completely separated the cardiac lobe from the diaphragmatic lobe near the ventral free margin of the lung, and as it approached the dorsal border the fissure became shallower (Plate XIX, fig. 2). In some lungs, the two fissures, which separated the cardiac lobe from the apical lobe and from the diaphragmatic lobe, were found to meet dorsal to the cardiac lobe (Plate XIX, fig. 3). In one lung, the fissure which separated the cardiac lobe from the diaphragmatic lobe was absent altogether, with the result that the cardiac lobe was completely attached to the diaphragmatic lobe and indistinguishable from it externally (Plate XIX, fig. 4).

With one exception, the right intermediate lobe was found to/

to be separated from the diaphragmatic lobe of the lung by a fissure which formed a canal for the caudal vena cava and the right phrenic nerve, however, in one lung, this fissure was absent and the intermediate lobe was fused to the diaphragmatic lobe, the foramen for the caudal vana cava and right phrenic nerve was absent and the vein lay on the mediastinal surface of the lobe.

In the left lung, the variations were less numerous presumably because the lobation is simpler. The cardiac notch between the apical and cardiac parts of the apical-cardiac lobe was found to vary in its extent with the result that in some lungs, there appeared to be no division of the apical-cardiac lobe into two parts, (Plate XX, fig. 1), while in other lungs, the division was quite distinct (Plate XX, fig. 2).

The fissure between the apical-cardiac and diaphragmatic lobes also varied in its extent. In the majority of the lungs examined, it extended to within 4cm of the dorsal border of the lung (Plate XX, fig. 3). In 3% of the lungs examined this fissure was found to extend into the lung from the ventral free margin a distance of 3cm only, and this was the only indication that the apical-cardiac lobe was separated from the diaphragmatic lobe (Plate XX, fig. 4).

It was found that in a pair of lungs the variation could affect one or both lungs, for example, on the external appearance of one pair of the lungs examined, the right lung was reduced to three lobes and the left lung was reduced to one lobe. It is a matter of conjecture as to why these variations should occur, and perhaps it would be of some value to consider how/

how the lobes are developed.

Flint (1906) has studied the development of the lobes in the pig and it may be assumed that their development follows similar lines in the sheep. His findings were that the growth of the first lateral bronchi produces projections in the mesoderm which are bounded by shallow grooves. As the growth proceeds, the size of the projections is increased and the shallow grooves become deeper; each of these main projections forms a lobe and the grooves form the interlobar fissures. Thus according to these observations in the right lung, the swellings over the apical lobar bronchus, the cardiac lobar bronchus, the intermediate lobar bronchus and the continuation of the main bronchus would form the apical, cardiac, intermediate and diaphragmatic lobes, and in the left lung, the swellings over the apical-cardiac lobar bronchus and the continuation of the left main bronchus would form the apical-cardiac and diaphragmatic lobes.

Flint has given as his opinion that one cause of the lobe formation is the very rapid growth of the first branches of the tree while the later branches, with the slower growth, fail to form furrows in the mesoderm which are deep enough to divide the lung further; another cause is that, during the period when the first branches are developing, the mesoderm is in a very plastic form and so moulds itself to the pressure of the growing bronchi. However, in a pig embryo of 12mm, fibrils are starting to appear in the mesoderm and gradually increase in numbers making the mesoderm firmer and less easily influenced by the growth of the bronchi.

Bressou/

Bressou (1946) has given some consideration to the question of pulmonary lobation and he makes the observation that the pulmonary lobation in mammals varies significantly according to the species. He has studied the evolution of the interlobar fissures in calves and puppies and is of the opinion that a definite development occurs in the fissures, during the early growth period, which is influenced to some extent by the growth of the thymus. He maintains that the conformation of the thorax plays a part in the determination of the lung lobation. In the majority of the domestic animals, the thorax is narrow anteriorly and wider posteriorly. He states, "De vorm en het volumen van de thorax, de ligging van de long binnen deze laatste, spelen een rol in de determinatie van de longlobulatie. Bij het meerendeel der huisdieren is de thorax nauw van vôôr en wijd van achter, anderzijds vermindert de ligging van het hart, vooraan gelegen tusschen de twee longen, nog de voorste longmassa. Aldus kan een uitleg gevonden worden voor de groote retrocardiale splitsing, die de diaphragmatische kwab vrij maakt".

Bressou is also of the opinion that the movement of the thorax during respiration have an influence on the fissuring. In this connection, he mentions work by Rouviere & Cordier (1933) on the adult human thorax which shows that cranial to the fifth rib the average inspiratory dilation amounts to 1 - 1.5cm and caudal to the sixth or seventh ribs the inspiratory dilation amounts to 2.5cm. The fissuring allows the caudal part of the lung the greatest facility for expansion, and the degree of fusion is dependent on the increase in the movement of/

of the ribs and the gradual curving of the diaphragm.

Bressou has made measurements in the dog and sheep which are comparable to those of Rouviere & Cordier in the human.

Narath (1901) has observed that the outer form of the lungs of the Sub-order Artiodactyla is characteristic so that they can be recognised immediately. With regard to the thorax, he has observed that, in the artiodactyls, it is very long and more or less laterally compressed, diminishing considerably at the cranial end. He has noted that the sternum is keel-shaped, the heart lies with its apex in the median plane, the thoracic part of the inferior vena cava is short and the post-cardiac space is small.

Serova (1950), in his paper on the lobation of the human lungs, points out that some monkeys have as many as six lobes in the right lung and four or five in the left lung and suggests that changes in lobation probably correspond to changes in the thoracic cavity, and in statics and dynamics.

It seems to be reasonable to assume that the purpose of the interlobar fissures is to allow the lungs to expand to their maximum during inspiration and thereby occupy all the available space, and that, in any particular species, the degree of lobation and extent of the fissures will largely depend on the early development of the lungs and the following factors which affect the space available for expansion:

1) The shape of the thorax, and the differences in the extent of the transverse inspiratory dilation in the different parts of the chest.

2) The rate of growth of the animal, and

3)/

3) The size of the thoracic contents other than the lungs.

It is more difficult to determine why so many individual variations should be present in a particular breed of sheep at a given age. It is possible that the same factors are responsible, because the multiplicity of origin of the British domestic breeds of sheep may well account for differences in the conformation of the thorax, the size of the thoracic contents, and the growth rate.

As explained earlier, the lobes are separated from each other either by the interlobar fissures or by interlobar connective tissue planes. A fissure may be increased by breaking down the connective tissue plane or, vice versa, it may be reduced in extent, in which case it will be replaced by the connective tissue plane.

The lobes are subdivided into broncho-pulmonary segments and the segments are separated from each other by intersegmental connective tissue planes. In some lungs an intersegmental plane may be broken down, with the result that a fissure is formed. This would explain how some of the variations occur in the interlobar fissures.

<u>Broncho-pulmonary segments.</u>

The idea that there were limited areas within a lobe was first formulated some time ago. Ewart (1889) was of the opinion that the lateral branches of the lobar bronchi of the right and left lungs are responsible for ventilating a definite -ly limited part of the lobe concerned.

Kramer and Glass (1932) were among the first to attempt

to/

to define these areas which were given the name of lung segments. They stated that "This unit, the broncho-pulmonary segment is a subdivision of a pulmonary lobe and represents not only an anatomic but also a pathologic unit. Each segment occupies a definite constant position in the pulmonary architecture and thoracic cavity and is supplied by a constantly placed bronchus whose orifice is situated in a large lobar bronchus and is easily visible to the bronchoscopist". Lucien and Weber (1936) when referring to similar subdivisions described them as "territories of ventilation".

In the human lung, from the observations of Aeby (1880), Ewart (1889) and Hernheisser & Kubat (1936), it can be appreciated that the pulmonary artery ramifies in a similar way to the bronchial tree, and although Narath (1901), Melnikoff (1924) and Appleton (1944) have pointed out that the arteries do not always reproduce the pattern of the bronchial tree, it may be said that the limitation of the broncho-pulmonary segment is emphasised by the pattern of the pulmonary arteries. As will be seen later, the study of the pulmonary artery in the lungs of the sheep substantiates the impression which has been formed with regard to the human lung.

In the human field, the segmental anatomy has been further investigated by a number of workers among whom Forster-Carter (1942), Jackson & Huber (1943), Brock (1946) and Rap (1947) have given detailed descriptions of the bronchial tree with reference to the broncho-pulmonary segments and their boundaries. These works emphasise the variations which occur in the broncho-pulmonary segments and the confusion which existed with regard

to/

to the nomenclature. In recent years the variations found in the broncho-pulmonary segments in the human lung have received intensive investigation by several American workers: Boyden & Hartmann (1946) and Scannell (1947) carried out an analysis on the left upper lobe, and Scannell & Boyden (1948) carried out an analysis on the right upper lobe. Berg, Boyden & Smith (1949) and Smith & Boyden (1949) analysed the variations in the left lower lobe and right lower lobe respectively.

In 1949, the International Congress of Oto-Rhino-Laryngology was held in London and the opportunity was taken to hold a meeting to discuss the nomenclature of the bronchial tree and the segments. A basic international nomenclature was recommended and this was later accepted by the Thoracic Society and recorded in Thorax (1950).

Between the segments there are intervening planes of connective tissue which as suggested by Appleton (1945) will be referred to as the intersegmental planes. Segments may be separated from one another by the breakdown of these planes. As far as is known, no specific work has been carried out on the segmental anatomy of the lungs of the sheep. However, Bressou & Vladutiu (1939) carried out a survey of 72 lungs belonging to various species of domestic mammals, amongst them ten lungs of sheep, with a view to analysing the branching of the bronchial tree and to dividing the lung up into a number of autonomous zones. They describe the left lung as consisting of two lobes, anterior and posterior, and the right lung as consisting of four lobes - anterior, middle, azygos and posterior. Later they describe how the lungs may be divided up into zones/

zones or territories of ventilation, each ventilated by a primary bronchus with its satellite vessels and nerves, and separate from neighbouring territories. Each division is pyramidal in shape, with its apex hilar in position, and with its base on the surface alongside neighbouring zones which systematize on the surface of the lung the distribution of the bronchial tree. They say: "Cette fragmentation n'est ni une vue de l'esprit, ni le résultat d'un artifice de dissection. Elle est marquée par la présence, dans le parenchyme pulmonaire, de cloisons conjonctivo-élastiques très évidentes sur l'organe foetal, bien visibles encore dans certaines espèces, comme le Boeuf, où les territoires de ventilation pulmonaire peuvent être séparés au scapel au grâce à ce cloisonnement périphérique".

They divide the lungs up into the following zones which are indicated in Plate XXI, figures 1, 2, 3 & 4.

<u>Left Lung</u> (Figs. 1, 2 & 4).

<u>Anterior lobe</u> - two zones - apical (A) & external cardiac (CE).

<u>Posterior lobe</u> - ten zones:

Four dorsal - dorsal anterior (D1)
dorsal antero-median (D2)
dorsal postero-median (D3)
dorsal posterior (D4).

Four ventral - ventral anterior (V1)
ventral antero-median (V2)
ventral postero-median (V3)
ventral posterior (V4).

One terminal (T).

One complementary (C) ventilated by the complementary bronchi.

<u>Right Lung</u> (Figs. 3 & 4).

Anterior/

Anterior Lobe - two zones - apical (AL) & anterior external cardiac (CaE).

Middle Lobe - posterior external cardiac (CpE).

Posterior Lobe - eleven zones:

Four dorsal - (D1, D2, D3 & D4) - as for left lung.

Four ventral - (V1, V2, V3 & V4) - as for left lung.

One terminal (T).

One complementary (C).

One internal cardiac zone (azygos lobe) (CI).

From the above, it will be appreciated that Bressou and Vladutiu have divided the left lung into eleven zones and the right lung into thirteen zones.

In the right lung, they describe the middle lobe as the posterior external cardiac zone and the azygos lobe as the internal cardiac zone. In the right and left lungs, the complementary zone is ventilated by the complementary bronchi about which they have this to say: "Celles-ci naissent en dedans ou en bas de la bronche souche, généralement après la deuxième bronche dorsale et avant la quatrième ventrale. Petites, ramifiées en bouquet étalé, elles se dirigent les unes en dedans et les autres en bas, assurent la ventilation d'une bonne partie de la face médiastinale du poumon, complétant les territoires déjà desservis par les bronches dorsales et ventral -es. Ces bronches complémentaires, comme on peut les appeler, varient numériquement de 2 à 8, mais on en trouve toujours chez tous les sujets. Exceptionnellement, on peut trouver une petite bronche complémentaire à direction externe, notament

entre/

entre deux bronches ventrales anormalement écartées".

In the following description of the broncho-pulmonary segments in the lungs of the sheep, an attempt has been made to adhere as closely as possible to the scheme and nomenclature accepted by the Thoracic Society for the human lung. At times this nomenclature was found to be unsuitable when applied to the sheep. This is consistent with what one would expect when a nomenclature based on a biped is applied to a quadruped; where the nomenclature has been altered that approved by the Thoracic Society will be given alongside. The attempt to adopt the scheme laid down for the human lung results in a description which differs greatly from that given by Bressou and Vladutiu (1939), but it is felt that it is justified for the following reasons: the lobation of the lungs has already been described, the left lung consisting of two lobes, the apical-cardiac and the diaphragmatic and the right lung consisting of four lobes, the apical, cardiac, intermediate and diaphragmatic. If the classifical definition of Kramer & Glass (1932) is accepted that a broncho-pulmonary segment is a subdivision of a pulmonary lobe and it is supplied by a constantly placed bronchus whose orifice is situated in a large lobar bronchus, then a segment cannot possibly be described as a lobe (Bressou & Vladutui) (1939). The licence to alter the number of segments in any given lobe is given because as Appleton (1945) states:. "The term broncho pulmonary segment has been restricted arbitrarily to those relatively large portions of lung which are ventilated by bronchi that have orifices into one of the lobar bronchi". Therefore, it is a matter of opinion as to

what/

what constitutes a relatively large portion of a lobe.

A recapitulation of the main bronchi will be a help to understanding the segmental anatomy of the lungs in the sheep. The right apical lobe is ventilated by a lobar bronchus which arises from the right lateral aspect of the trachea approximately 5cm cranial to the bifurcation of the trachea. The trachea divides into the right and left main bronchi,and from the ventral lateral aspect of the right bronchus, apprpximately 1.5cm caudal to the bifurcation of the trachea, the right cardiac lobar bronchus arises and from the medial aspect of the same opening the right intermediate lobar bronchus; caudal to this point the right main bronchus ventilates the diaphragmatic lobe only and is known as the diaphragmatic lobar bronchus. The left main bronchus gives off from its ventral lateral aspect the bronchus to the left apical-cardiac lobe approximate -ly 1.6cm caudal to the bifurcation of the trachea,and caudal to this point it is known as the left diaphragmatic lobar bronchus.

Following a study of the lungs of eighteen sheep carried out by means of air inflation and gelatin injection of the segments and by very fine corrosion casts of the bronchial tree, an analysis has been made of the usual position and boundaries of the broncho-pulmonary segments. Generally speaking each broncho-pulmonary segment may be described as being wedge-shaped, with the apex directed towards the origin of the segmental bronchus and the base forming part of the surface of the lung.

In the following description the lungs are divided into lobes/

lobes and the segments are described under that lobe of which they are a part.

The right apical lobe: the right apical lobar bronchus divides into cranial and caudal bronchi. These bronchi are considered to be segmental bronchi ventilating respectively the cranial (Acr) and caudal (Aca) broncho-pulmonary segments of the right apical lobe. The right apical lobe of the sheep is quite different from the right upper lobe of the human lung, and the international nomenclature is not applicable. The cranial broncho-pulmonary segment (Acr) comprises the cranial part of the right lung, its caudal boundary is marked by the intersegmental plane which extends from the cardiac notch in a dorsal and medial direction (Plate XXII, fig. 1 & 2; Plate XXIII, fig. 1 & 2; Plate XXIV, fig. 1). The caudal segment (Aca) forms the caudal part of the right apical lobe. Its cranial boundary is formed by the plane between it and the cranial segment; the caudal boundary is formed, in its ventral part, by the fissure which extends between the right apical lobe and the right cardiac lobe, in its dorsal part, by the intersegmental plane which lies between the caudal segment and the cranial dorsal part (apical segment) of the right diaphragm-atic lobe, and starting at the dorsal part of the cardiac lobe runs in a dorsal and medial direction (Plate XXII, fig. 1 & 2; Plate XXIV, fig. 1).

The right cardiac lobe: the right cardiac lobar bronchus gives off a lateral bronchus from its dorsal lateral aspect about 11cm from its origin. This lateral bronchus ventilates the lateral and dorsal area of the right cardiac lobe which is known/

known as the lateral segment (Cl). The continuation of the lobar bronchus is known as the medial segmental bronchus and it ventilates the ventral and medial part of the lobe which is known as the medial segment (Cm). The lateral and medial segments of the right cardiac lobe in the sheep's lung bear comparison with the lateral and medial segments of the right middle lobe in the human lung. The demarcation between the lateral and medial segments may be seen on the lateral surface of the lobe, approximately halfway between its dorsal and ventral extremities, where the intersegmental plane forms an almost horizontal boundary extending from the caudal to the cranial border. The plane extends in a medial and dorsal direction through the depth of the lobe thus dividing it into a smaller dorsal and lateral part and a larger ventral and medial part. (Plate XXII, fig. 1; Plate XXIII, fig. 2; Plate XXIV, fig. 1).

In some lungs, the lateral segmental bronchus ventilates a much smaller area; however, in these cases, a second lateral segmental bronchus is given off by the lobar bronchus which ventilates the complementary part of the cardiac lobe which usually forms the lateral segment.

<u>The right intermediate lobe</u>: in the sheep, the right intermediate lobar bronchus arises from the right main bronchus in common with the right cardiac lobar bronchus. Approximately 10mm from its origin, the intermediate lobar bronchus gives rise to a caudal bronchus. This bronchus ventilates the dorsal segment (Id) of the intermediate lobe which forms the dorsal medial part of the wall of the foramen for the caudal vena cava; the lobar bronchus is continued as the ventral segmental/

segmental bronchus and it ventilates the ventral segment (Iv). The boundaries of the dorsal segment are formed, on the dorsal aspect, by the plane between the intermediate and diaphragmatic lobes (Plate XXIV, fig. 1), and on the ventral aspect, by the plane which lies horizontally in the medial wall of the caval foramen and extends from the base of the lobe to the ventral segmental bronchus between the dorsal and ventral segments (Plate XXIV, fig. 1). The ventral segment forms the ventral part of the lobe.

The foramen for the caudal vena cava and the right phrenic nerve is formed as follows: the lateral wall of the foramen is formed by the mediastinal surface of the diaphragmatic lobe, the dorsal wall and part of the medial wall is formed by the dorsal segment of the intermediate lobe, while the ventral wall and the ventral part of the medial wall is formed by the ventral segment (Plate XXIII, fig. 2).

<u>The right diaphragmatic lobe</u>: the right diaphragmatic lobar bronchus gives rise to two ventral lateral bronchi which ventilate the ventral basal (Dvb) and lateral basal (Dlb) segments, two dorsal bronchi which ventilate the apical (Da) and subapical (Dsa) segments and a ventral bronchus which ventilates the medial basal segment (Dmb); the continuation of the lobar bronchus ventilates the dorsal basal segment (Ddb).

The first ventral lateral bronchus ventilates what is known in the sheep as the ventral basal segment (Dvb). In the human, this segment is known as the anterior basal segment, but as the term "anterior" is unsuitable for use in a quadruped the term "ventral" is used. This segment forms the cranial ventral/

ventral part of the lobe (Plate XXII, fig. 1 & 2; Plate XXIV, fig. 1). Its cranial boundary is indicated by the fissure which extends between the cardiac and diaphragmatic lobes. The caudal boundary is formed by the intersegmental plane between the ventral basal (Dvb) and the adjacent lateral basal (Dlb) segment; this intersegmental plane is marked on the lateral surface by a line which starts approximately one third of the way along the basal border and runs in a cranial and dorsal direction towards the dorsal border of the lobe (Plate XXII, fig. 1). It extends through the depth of the lobe and may be seen on the diaphragmatic surface (Plate XXIII, fig. 2), where it is marked by a line which starts one third of the way along the basal border and passes to the caval foramen (Plate XXIII, fig. 2); near the lobar bronchus it separates the ventral basal segment from the medial basal segment (Plate XXIII, fig. 2). The dorsal boundary is formed by the plane lying between the ventral basal and apical segments; this plane is marked on the lateral surface by a line which lies approximately on a level with the dorsal boundary of the cardiac lobe (Plate XXII, fig. 1), and it extends in a ventral and medial direction through the depth of the lobe to the ventral basal segmental bronchus.

The first dorsal bronchus ventilates the apical segment (Da) of the diaphragmatic lobe, which corresponds to the apical segment of the right lower lobe in the human lung. This apical segment forms the cranial dorsal part of the lobe (Plate XXII, fig. 1 & 2; Plate XXIV, fig. 1); its cranial boundary has already been described as being the intersegmental plane/

plane which lies between it and the caudal segment (Aca) of the right apical lobe (Plate XXII, fig. 2), and its ventral boundary is marked by the plane which lies between it, the lateral segment (Cl) of the cardiac lobe, the ventral basal segment (Dvb) and the lateral basal segment (Dlb). The line marking the lateral extent of this plane varies from V-shaped to horizontal depending on the size of the segment (Plate XXII, fig. 1 & 2). From the caudal point of the line denoting the lateral extent of this plane, a line can be drawn over the dorsal border to the medial aspect of the lobe, where it runs in a cranial and ventral direction (Plate XXII, fig. 1 & 2; Plate XXIV, fig. 1); this marks the external limit of the plane which lies between the apical (Da) and the subapical (Dsa) segments and runs in a ventral and cranial direction to form the caudal boundary of the apical segment.

The lateral basal segment (Dlb) forms the wedge-shaped area of the diaphragmatic lobe which lies between the ventral basal (Dvb) and dorsal basal (Ddb) segments. It occupies the middle, ventral and lateral part of the lobe and corresponds to the lateral basal segment of the right lower lobe in the human lung (Plate XXII, fig. 1; Plate XXIII, fig. 2). Its cranial boundary is formed by the plane which lies between it and the ventral basal segment, and has already been described. Its caudal boundary is formed by the plane which lies between it and the dorsal basal segment; on the lateral surface of the lung, this plane is marked by a line which starts from the basal border of the diaphragmatic lobe, approximately two thirds of the way along its length from the cranial extremity, and runs/

runs in a cranial and dorsal direction; from the lateral surface, the plane extends through the depth of the lobe in a ventral and slightly medial direction to the diaphragmatic surface of the lobe (Plate XXII, fig. 1). The dorsal boundary of the lateral basal segment is formed by a plane lying between it and the subapical segment (Dsa) (Plate XXII, fig. 1 & 2). On the lateral surface of the lobe, this plane is indicated by a line running in a caudal and dorsal direction from the caudal part of that plane which lies between the apical (Da) and the ventral basal segments; it runs in a medial, cranial and ventral direction from the external surface towards the lobar bronchus. Medially, the lateral basal segment is separated from the medial basal segment (Dmb) by an intersegmental plane which runs through the lung in a cranial, dorsal and medial direction from the diaphragmatic surface. (Plate XXIII, fig. 2).

The subapical segment (Dsa) of the diaphragmatic lobe is without an analogy in the human lung. However, as this segment is consistently present in the sheep lung, and as it lies caudal in position to the apical segment (Da), it is known as the subapical segment (Plate XXII, fig. 2). The cranial boundary of this segment is formed by the intersegmental plane between it and the apical segment, and has already been described (Plate XXII, fig. 2; Plate XXIV, fig. 1); the ventral boundary is formed by the plane between it and the lateral basal segment (Dlb), and this has also been described (Plate XXII, fig. 1). Caudally, the boundary of the subapical segment is formed by the plane which lies between it and the dorsal basal/

basal segment (Ddb); externally, this plane is marked by a line drawn medially from the caudal extent of the ventral boundary over the dorsal border (Plate XXII, fig. 1 & 2; Plate XXIV, fig. 1). From the surface, it extends in a cranial and ventral direction through the lung to the lobar bronchus. Medially, the subapical segment is separated from the medial basal segment (Dmb) by a plane which is marked externally by a horizontal line drawn slightly ventral to the lobar bronchus (Plate XXIV, fig. 1).

The medial basal segment (Dmb) is also without an analogy in the human lung. It must be made quite clear that the medial basal segment of the right lower lobe in the human lung does not bear comparison with the medial basal segment of the right diaphragmatic lobe in the sheep's lung. In the human, the medial basal segment refers to the area which is known as the intermediate lobe in the sheep, but, in the human, this area is not separated from the diaphragmatic lobe and does not have lobar status. The medial basal segment is a wedge-shaped area of pulmonary tissue whose base is to be seen in the medial part of the diaphragmatic surface of the diaphragmatic lobe (Plate XXIII, fig. 2). Laterally, the medial basal segment is separated from the lateral basal (Dlb) and ventral basal (Dvb) segments by the intersegmental planes which have already been described (Plate XXII, fig. 1), while medially, the segment is separated from the subapical segment (Dsa) by a horizontal connective tissue plane (Plate XXIV, fig. 1). Caudally, the segment is bounded by the intersegmental plane which lies between it and the dorsal basal segment (Ddb); on the/

the diaphragmatic surface, this plane is marked by a transverse line which runs from the mediastinal aspect of the lung to the middle of the surface, and from this external demarcation, the plane passes in a cranial and dorsal direction towards the lobar bronchus (Plate XXIII, fig. 2).

The dorsal basal segment (Ddb) forms the caudal part of the diaphragmatic lobe and it is ventilated by the continuation of the diaphragmatic lobar bronchus, after the above mentioned segmental bronchi have been given off (Plate XXII, fig. 1 & 2; Plate XXIV, fig. 1). The dorsal basal segment is analogous with the posterior basal segment of the right lower lobe in the human; however, the term "posterior" was considered to be inappropriate in the sheep and the term "dorsal" was introduced instead. The cranial boundary is formed dorsally by the intersegmental plane between the segment and subapical segment (Dsa) (Plate XXII, fig. 2), and ventrally by the intersegmental plane between the segment and medial basal segment (Dmb) (Plate XXIV, fig. 1). The lateral boundary is formed by the intersegmental plane between the segment and lateral basal segment (Dlb) (Plate XXII, fig. 1); the position of these several intersegmental planes has been described in connection with the other segments.

In the left lung, the left main bronchus gives off, from its ventral lateral aspect, a bronchus to the apical cardiac lobe approximately 1.6cm from the bifurcation of the trachea.

<u>The apical-cardiac lobe:</u> the apical-cardiac lobar bronchus soon divides into two bronchi, a bronchus which runs in a cranial direction to ventilate the apical segment (ACa) of the/

the apical-cardiac lobe, and a bronchus which continues in a ventral and lateral direction to ventilate the cardiac segment (ACc) of the apical-cardiac lobe. The bronchial tree of the human lung in this region does not bear comparison with that of the sheep and for this reason no attempt has been made to follow the international nomenclature.

The apical segment (ACa) forms the cranial part of the left lung; it is separated by intersegmental connective tissue planes from the cardiac segment (ACc) caudally and ventrally, from the ventral basal segment (Dvb) of the left diaphragmatic lobe caudally and from the apical segment (Da) of the diaphragm -atic lobe caudally and dorsally (Plate XXIII, fig. 1). The plane between the apical and cardiac segments of the apical-cardiac lobe is indicated on the lateral surface of the lung by a line, drawn either in a horizontal or in a caudal dorsal direction, from the cardiac notch to the line of the ventral fissure between the apical-cardiac and diaphragmatic lobes (Plate XXIII). From this external limit, the plane runs in a medial and slightly dorsal direction through the lung towards the cardiac segmental bronchus. The caudal boundary is indicated by the line of the fissure between the apical-cardiac and diaphragmatic lobes being continued in a dorsal direction; from this external demarcation, the plane extends in a medial and slightly cranial direction (Plate XXIII, fig. 1). As mentioned above, the apical segment of the apical-cardiac lobe is bounded by the apical segment of the diaphragmatic lobe dorsally and caudally. In the description of the bronchial tree, it will be pointed out that these segments vary in size, and/

and consequently, the position of the intersegmental plane between them will alter. Usually the position of the intersegmental plane is indicated by an external line starting on the dorsal border approximately on a level with the bifurcation of the trachea, and from this point, it runs in a caudal and ventral direction to the caudal boundaries of the segment described above which it meets approximately 2.3cm ventral to the dorsal border of the lung (PlateXXIII, fig. 1). From the external surface, the plane passes in a medial direction through the lung towards the left main bronchus (Plate XXIV, fig. 2).

The boundaries of the cardiac segment (ACc) are fairly clear. Dorsally, it is separated by the intersegmental plane which lies between it and the apical segment (ACa) (Plate XXIII, fig. 1), while caudally, it is separated from the diaphragmatic lobe by a fissure which extends dorsally from the ventral margin (Plate XXIII, fig. 1; Plate XXIV, fig. 2). The length of the fissure varies, and if it is absent, the cardiac segment is separated from the diaphragmatic lobe by a plane of connective tissue which follows the line of the fissure.

<u>The left diaphragmatic lobe</u>: after it has given off the apical-cardiac lobar bronchus, the left main bronchus is continued as the left diaphragmatic lobar bronchus, and, like the right diaphragmatic lobar bronchus, it gives rise to two ventral lateral bronchi which ventilate the ventral basal (Dvb) and lateral basal (Dlb) segments, two dorsal bronchi which ventilate the apical (Da) and subapical (Dsa) segments and a ventral bronchus which ventilates the medial basal segment (Dmb).

The/

The diaphragmatic lobar bronchus is then continued as the segmental bronchus which ventilates the dorsal basal segment (Ddb). The position and boundaries of these segments are very similar to those of the corresponding segments in the diaphragmatic lobe of the right lung (Plate XXII, fig. 2; Plate XXIII, fig 1 & 2; Plate XXIV, fig. 2). The ventral basal, lateral basal, dorsal basal and apical segments are analagous with the anterior basal, lateral basal, posterior basal and apical segments of the left lower lobe in the human lung. As in the right lung, the subapical and medial basal segments are additional segments which are present in the sheep and not in the human.

In the sheep therefore, the right lung is considered to be composed of four lobes and twelve segments, and the left lung of two lobes and eight segments. Reference has already been made to the segments in the human lung, but it is of interest to compare this present analysis with that of Bressou and Vladutiu (1939).

In the right lung, Bressou and Vladutiu divided the anterior lobe into apical (Ap) and anterior external cardiac (CaE) zones (Plate XXI, fig. 3); these are clearly homologous with the cranial (Acr) and caudal (Aca) segments of the right apical lobe (Plate XXII, fig. 1). They considered that the middle lobe forms a zone which they term the posterior external cardiac (CpE) (Plate XXI, fig. 3). According to the definition of a segment drawn up by Kramer and Glass (1932), and to which Bressou and Vladutiu made no reference, a segment is a subdivision of a lobe, and therefore a lobe cannot be classed as

a/

a segment; accordingly the middle lobe, cardiac lobe, is considered to be composed of a lateral (Cl) and a medial (Cm) segment (Plate XXII, fig. 1).

In the scheme drawn up by Bressou and Vladutiu, the right azygos lobe is included as one of the zones in the right posterior lobe, and is known as the internal cardiac zone (CI) (Plate XXI, fig. 4). In this analysis, for the reasons just mentioned, the right intermediate lobe has been subdivided into dorsal (Id) and ventral (Iv) segments (Plate XXIII, fig. 2).

The right diaphragmatic lobe has been divided into eleven zones by Bressou and Vladutiu. The validity of the internal cardiac zone (CI) has already been considered, but there remain the four dorsal, four ventral, one terminal and one complementary zones. As mentioned before the segment has been arbitrarily restricted to large areas of a lobe, and it is largely a matter of opinion as to how many segments may be considered to be present in certain lobes when the segmental bronchi are formed as lateral branches rather than as a well marked division of the lobar bronchus.

In the analysis of Bressou and Vladutiu, the ventral anterior zone (V1) is homologous with the ventral basal segment (Dvb) as described above, the ventral antero-median zone (V2) with the lateral basal segment (Dlb), the dorsal anterior zone (D1) with the apical segment (Da) and the dorsal antero-median zone (D2) with the subapical segment (Dsa) (Plate XXI & XXII). The complementary zone (C) is ventilated by several bronchi, but that part of it which is ventilated by the most cranial of these/

these bronchi will correspond to the medial basal segment (Dmb) (Plate XXI, fig. 4; Plate XXIII, fig. 2). The remaining ventral postero-median (V3), ventral posterior (V4), dorsal postero-median (D3) and dorsal posterior (D4) zones, the terminal zone (T) and the remaining part of the complementary zone (C) are all included in the dorsal-basal segment (Ddb) described above (Plate XXI, fig. 3 & 4; Plate XXII, fig. 1 & 2; Plate XXIII, fig. 2).

In the left lung, Bressou and Vladutiu consider that the anterior lobe consists of two zones - the apical (A) and the external cardiac (CE) - and these are homologous with the apical (ACa) and cardiac (ACc) segment of the apical-cardiac lobe which have been described (Plate XXI, fig. 1; Plate XXIII, fig. 1).

They have subdivided the posterior lobe into ten zones:- four dorsal, four ventral, one terminal and one complementary. As in the right lung, the ventral anterior (V1), ventral antero-median (V2), dorsal anterior (D1) and dorsal antero-median (D2) zones are homologous with the ventral basal (Dvb), lateral basal (Dlb), apical (Da) and subapical (Dsa) segments respectively, and part of the complementary zone (C) is equivalent to the medial basal segment (Dmb). The remaining zones and part of the complementary zone are included in the dorsal basal segment (Ddb) (Plate XXI, fig. 1 & 2; Plate XXIII, fig. 1; Plate XXIV, fig. 2).

Forster-Carter (1942) and Appleton (1944) mentioned that a broncho-pulmonary segment may be further subdivided into zones which are ventilated by branches of the segmental bronchus. The/

The presence of these zones in the lungs of sheep has been substantiated by injecting them with gelatin solutions in a similar manner to that described for the segments. These areas are termed subsegments, and like the segments, they are separated from each other by connective tissue planes which are known as inter-subsegmental planes. Reference is made to the position of these subsegments during the description of the bronchial tree.

To summarise, each lung is in the form of a flattened cone presenting for description a base, an apex, two surfaces and two borders. The right lung is much larger than the left, and consists of four lobes, an apical, a cardiac, an intermediate and a diaphragmatic; the left lung consists of two lobes, an apical-cardiac and a diaphragmatic. The lobes are separated from each other by external fissures.

Following a survey of one hundred and fifty lungs, an analysis is given of the variations which occurred in the extent and depth of the fissures between the lobes. The purpose of the fissures appears to be to allow the lungs to make full use of the space available in the thorax during inspiration. The extent of the fissures appears to depend on the early development of the lungs, and on a number of factors which affect the space available for expansion.

The air is conducted to the respiratory part of the lungs by the trachea which divides into the main bronchi, and these give rise to the lobar bronchi. The lobar bronchi give rise to the segmental bronchi which, in turn, give rise to the subsegmental bronchi. The bronchi continue to subdivide till the cartilage/

cartilage plates are lost, when they are known as terminal bronchioles. Several bronchiolar subdivisions take place before the respiratory bronchioles are formed; in the sheep, following a study of three segments, it was found that there are in the region of sixteen bronchial subdivisions from the segmental bronchi to the terminal bronchioles, and a further fifteen bronchiolar subdivisions.

The broncho-pulmonary segments of the lung have been described following a survey of fifteen sheep. The basic international nomenclature which has been accepted by the Thoracic Society for the segments of the human lung, has been adhered to as far as possible, but certain terms have had to be altered because they are not applicable to a quadruped.

In the right lung, the apical lobe has been subdivided into cranial and caudal segments, the cardiac lobe into lateral and medial segments, the intermediate lobe into dorsal and ventral segments and the diaphragmatic lobe into ventral basal, lateral basal, dorsal basal, apical, subapical and medial basal segments. In the left lung, the apical-cardiac lobe has been divided into apical and cardiac segments, and the diaphragmatic lobe has been subdivided in a similar manner to the right diaphragmatic lobe.

Description of the Bronchial Tree.

As described before, the trachea conducts the air from the larynx to the lungs. On a level with the third rib and about 5cm before its bifurcation into the right and left main bronchi, the trachea gives rise to the right apical lobar bronchus/

bronchus from its right lateral aspect. On a level with the fifth rib the trachea divides into right and left main bronchi, the right arising at an angle of approximately 22 degrees to the long axis of the trachea and the left at an angle of approxiamtely 26.5 degrees to the long axis of the trachea.

The right main bronchus gives rise to the cardiac and intermediate lobar bronchi from a common opening in its ventral aspect, and it is then continued as the diaphragmatic lobar bronchus.

The left main bronchus gives rise to the apical-cardiac lobar bronchus from its ventral lateral aspect, and is then continued as the diaphragmatic lobar bronchus.

The right and left diaphragmatic lobar bronchi give off from their ventral lateral, dorsal, and ventral aspects, smaller bronchi which ventilate broncho-pulmonary segments.

Narath (1901) in his description of the bronchial tree of the lung of the sheep observes that bronchi arise from the ventral lateral aspect of the stem bronchi, nearer the trachea on the right side than on the left. In this work it has been observed that, as a general rule, the cardiac and intermediate lobar bronchi arise from the right main bronchus at a point nearer the trachea than the point at which the apical-cardiac lobar bronchus arises from the left main bronchus; and that the first ventral lateral bronchus given off by the right diaphragmatic lobar bronchus arises nearer the trachea than the corresponding bronchus given off by the left diaphragmatic lobar bronchus. However, the positions are not constant for the other ventral lateral bronchi.

This/

This survey of the bronchial tree has been carried out on the lungs of fifty sheep by means of corrosion casts and dissections, and by serial sections of the right cardiac lobe of one of these. The following description is intended to give a general plan for the ramification of the bronchial tree. The bronchi are described according to the areas of the lung which they ventilate; the basic international nomenclature accepted by the Thoracic Society is used wherever possible, but its adoption is unsuitable for certain bronchi because of the postural differences in the quadruped, and alternative names have been used. The terms "proximal" and "distal" are used to refer to the position of bronchi in relation to the main axis of the tree.

Right Lung.

The right apical lobar bronchus (RAL) (right upper lobar bronchus): this bronchus arises from the right ventral lateral aspect of the trachea approximately 5cm above its point of bifurcation into the right and left main bronchi. The bronchus runs in a ventral lateral and slightly caudal direction for a distance of 8mm. At this point, it divides dichotomously into two bronchi, a cranial bronchus (Cr) which ventilates the cranial part of the right apical lobe, and a caudal bronchus (Ca) which ventilates the caudal part of the right apical lobe. Since these two bronchi are large branches of a lobar bronchus and ventilate independent areas of lung tissue they may be termed broncho-pulmonary segmental bronchi, and the areas ventilated may be termed the cranial broncho-pulmonary segment and the caudal broncho-pulmonary segment of the right apical lobe/

lobe. (Plate XXV, XXVI and XXVII).

The cranial broncho-pulmonary segmental bronchus (Cr) runs at first in a ventral and lateral direction; approximate -ly 10mm from its origin, the bronchus gives off a subsegmental bronchus (Cra) from its cranial dorsal aspect, and then it bends cranially to run in a ventral, lateral and cranial direction (Plate XXVIII). About 13mm from the point of origin of the subsegmental bronchus (Cra), a second subsegmental bronchus (Crl) arises from the caudal ventral aspect of the parent bronchus (Plate XXVIII). The continuation of the segmental bronchus may be considered to be the subsegmental bronchus (Crv) (Plate XXVIII).

The subsegmental bronchus (Cra) courses in a cranial and horizontal direction to ventilate the cranial dorsal area of the cranial bronchi-pulmonary segment (Plate XXVIII). This area is an independent area of lung tissue within the cranial broncho-pulmonary segment and may be termed the apical subsegment, and therefore the bronchus (Cra) may be termed the apical subsegmental bronchus. It gives off several collateral bronchi from its dorsal, ventral and medial aspects; these collateral bronchi decrease in size from first to last. The dorsal bronchi (Crad) are the largest and they run in a dorsal direction to terminate at the dorsal border of the apical subsegment; they ventilate the dorsal part of the apical subsegment. Each dorsal bronchus has small collateral branches arising from its cranial, caudal, lateral and medial aspects (Plate XXVIII). The ventral and medial bronchi are much smaller. The ventral bronchi (Crav) run in a ventral, lateral and/

and slightly cranial direction giving off several small collateral rami which ventilate the ventral part of the apical subsegment. The medial bronchi (Cram) run medially and ventilate the medial part of the apical subsegment (Plate XXVIII).

The subsegmental bronchus (Crl) runs at first in a ventral, lateral and slightly cranial direction, after which it bends caudally and inclines medially to run in a ventral direction; towards its termination the bronchus divides into two terminal bronchi which incline medially and run in a caudal direction to end near the mid-line of the thoracic cavity in the ventral and caudal tip of the cranial broncho-pulmonary segment. This bronchus (Crl) ventilates an independent lateral area of the cranial broncho-pulmonary segment and it may be termed the cranial lateral subsegment; the bronchus may therefore be termed the cranial lateral subsegmental bronchus (Plate XXVIII). Collateral branches are given off from its cranial, caudal and lateral aspects. The cranial bronchi (Crlcr) run in a cranial, ventral and lateral direction to ventilate the cranial part of the cranial lateral subsegment; small rami arise from the cranial, caudal, lateral and medial aspects of the collateral bronchi (Plate XXVIII). The lateral bronchi (Crll) run in a ventral and lateral direction to ventilate the lateral part of the cranial lateral subsegment (Plate XXVIII). The caudal bronchi (Crlca) run in a ventral and caudal direction to ventilate the caudal part of the cranial lateral subsegment, and small rami arise from their cranial, caudal, lateral and medial aspects (Plate XXVIII).

The/

The subsegmental bronchus (Crv) runs at first in a cranial and ventral direction, gradually it inclines medially, and finally it divides into two terminal bronchi approximately 27mm from its origin; the area ventilated by the bronchus (Crv) and its rami may be termed the ventral subsegment, and the bronchus may be termed the ventral subsegmental bronchus (Plate XXVIII). Approximately 11mm from the origin of the bronchus (Crv) a collateral bronchus arises from its lateral aspect; this lateral bronchus (Crvl) runs in a cranial and horizontal direction inclining slightly medially; it gives rise to small rami at first from its lateral and medial aspects, and later from its lateral, medial, dorsal and ventral aspects; it ventilates the dorsal part of the ventral subsegment (Plate XXVIII). The terminal bronchi of the bronchus (Crv) may be described as dorsal (Crvd) and ventral (Crvv), they curve medially to pass towards the left side of the median plane and ventilate the area of the ventral subsegment on the left side of the thoracic cavity. Small bronchi arise from the cranial, caudal, dorsal and ventral aspects of these terminal bronchi. (Plate XXVIII).

The caudal broncho-pulmonary segmental bronchus (Ca) runs in a caudal, ventral and lateral direction for a distance of 15mm when it divides into two bronchi, a dorsal bronchus (Casa) and a ventral bronchus (Cal). (Plate XXVIII). These bronchi ventilate independent areas of lung tissue within the caudal broncho-pulmonary segment and may be termed subsegmental bronchi.

The subsegmental bronchus (Casa) runs in a caudal and slightly/

slightly dorsal direction for approximately 25mm before dividing into two smaller terminal bronchi; it ventilates an independent dorsal caudal area of the caudal broncho-pulmonary segment which may be termed the subapical subsegment and is known as the subapical subsegmental bronchus. It gives off a dorsal collateral bronchus (Casad) from its dorsal aspect, approximately 6mm from its origin, which runs in a dorsal and caudal direction to ventilate the cranial and dorsal part of the subapical subsegment. Collateral rami arise from its cranial dorsal, caudal ventral, medial and lateral aspects; of these, the cranial dorsal bronchi are the largest decreasing in size from first to last. In some lungs, this dorsal collateral bronchus (Casad) arises from the dorsal aspect of the segmental bronchus (Ca) before it has divided into the subsegmental bronchi (Casa) and (Cal) (Plate XLIV, fig. 1). In these cases, the length of the broncho-pulmonary segmental bronchus (Ca) before its division into the bronchi (Casa) and (Cal) is 20mm, the length of the bronchus (Casa) before it divides into the terminal bronchi is 15mm, and the area ventilated by the bronchus (Casad) may be considered to be a subsegment. About 10mm from the point at which the dorsal collateral bronchus arises, the subapical bronchus (Casa) gives off a lateral collateral bronchus from its lateral aspect, and about the same level a small medial bronchus from its medial aspect. The dorsal terminal bronchus (Casadt) runs in a dorsal and caudal direction to ventilate a dorsal and caudal part of the subapical subsegment; it gives off small collateral bronchi from its dorsal, lateral and medial aspects (Plate XXVIII).

The/

The ventral terminal bronchus (Casavt) runs in a caudal, horizontal and slightly lateral direction, giving off collater -al bronchi, and supplying that area of the subapical sub-segment lateral and ventral to the area supplied by the dorsal terminal bronchus (Plate XXVIII).

The subsegmental bronchus (Cal) runs in a caudal, ventral and lateral direction, and passing downward in the middle of the caudal and ventral part of the right upper lobe, it vent-ilates what may be termed the caudal lateral subsegment of the caudal broncho-pulmonary segment; for this reason, it is known as the caudal lateral subsegmental bronchus (Plate XXVIII). Collateral bronchi arise from the cranial, caudal, lateral and medial aspects of this bronchus (Cal); the cranial bronchi (Calcr) run in a cranial, ventral and lateral direction to supply the cranial part of the caudal lateral subsegment; the caudal bronchi (Calca) run in a caudal, ventral and lateral direction to supply the caudal part of the caudal lateral sub-segment; the medial bronchi (Calm) run in a medial and ventral direction to supply the medial part of the caudal lateral sub-segment. These collateral bronchi have small rami arising from their cranial, caudal, medial and lateral aspects. (Plate XXVIII).

<u>The right cardiac lobar bronchus</u> (C) (right middle lobar bronchus): this bronchus and the right intermediate lobar bronchus (I) arise from the ventral lateral aspect of the right main bronchus by a common opening approximately 15mm from the bifurcation of the trachea (Plate XXVII). The right inter-mediate lobar bronchus is sometimes described as arising from the/

the medial aspect of the right cardiac lobar bronchus close to its origin.

The cardiac lobar bronchus (C) runs in a ventral and lateral direction to ventilate the area of the right lung known as the cardiac or middle lobe; it lies in a subpleural position on the caudal medial border of the lobe, and about 11mm from its point of origin it gives rise to the lateral bronchopulmonary segmental bronchus (L) (Plate XLV) (Sheet 1, figs. 6 - 9; Sheet 2, figs. 1 - 4).

The lateral segmental bronchus (L) runs in a lateral direction for about 8mm when it gives off a dorsal subsegmental bronchus (Ld) from its dorsal aspect (Plate XLV). This bronchus (Ld) runs in a dorsal direction to ventilate the narrow dorsal part of the lobe (Sheet 1, figs. 1 - 7). Almost immediately, the lateral bronchus (L) bends ventrally and gives off a caudal subsegmental bronchus (Lca) (Plate XLV); this runs in a lateral, caudal and ventral direction to ventilate the caudal lateral part of the segment (Sheet 2, figs. 5 - 9). At the same level, a cranial subsegmental bronchus (Lcr) arises from the segmental bronchus (L); it runs at first in a cranial direction and then bends in a dorsal direction to ventilate the cranial dorsal part of the lobe (Plate XLV) (Sheet 2, figs. 1 - 9); it gives off a ramus which runs in a ventral diraction. The third and largest subsegmental bronchus to be given off by the lateral segmental bronchus at this level is the lateral bronchus (Ll); this bronchus runs in a lateral direction and gives off cranial, ventral and dorsal rami, before dividing into cranial and caudal terminal rami. It ventilates the/

the cranial lateral part of the segment (Plate XLV) (Sheet 2, figs. 1 - 8). The lateral segmental bronchus (L) is continued in a ventral and slightly lateral direction as the ventral subsegmental bronchus (Ld) which ventilates the cranial, lateral and ventral part of the segment. This bronchus (Lv) moves gradually towards the cranial lateral part of the lobe and gives off several rami from its lateral, cranial and medial aspects (Plate XLV) (Sheet 3, figs. 3 - 5; Sheets 4 & 5).

The lobar bronchus is continued as the medial bronchopulmonary segmental bronchus (M) (Plate XLV). At first it lies in a subpleural position but gradually moves towards the centre of the medial border. About 8mm below its origin, the medial segmental bronchus gives off a caudal subsegmental bronchus (Mca) (Plate XLV) (Sheet 5, figs. 2 - 4).

The caudal subsegmental bronchus (Mca) runs in a ventral, caudal and lateral direction and a short distance from its origin it gives off a lateral ramus (Mcal1); this bronchus passing in a lateral and ventral direction, divides into cranial and caudal rami which ventilate the caudal lateral part of the lobe at this level. (Plate XLV) (Sheet 5, figs. 3 - 6; Sheet 6, figs. 1 - 4). The bronchus (Mca) continues in a ventral, lateral and caudal direction, giving off cranial, caudal, medial and lateral rami which ventilate the respective areas of the caudal part of the lobe (Plate XLV) (Sheet 7, figs. 1 - 6; Sheet 8, figs. 1 - 6). The bronchus gradually approaches the caudal lateral border of the lobe and extends to the ventral tip of the lobe. The caudal subsegmental bronchus, therefore, ventilates the caudal part of the medial segment from/

from the level of its origin to the ventral tip of the lobe (Sheets 9, 10, 11, 12, 13 & 14).

The medial segmental bronchus now becomes deep in position and, approximately 2mm below the level at which the caudal subsegmental bronchus (Mca) arises, it gives off the first cranial subsegmental bronchus (Mcr1) (Plate XLV) (Sheet 6, fig. 1). This bronchus runs in a cranial and ventral direction, and gives off a dorsal ramus (Mcr1) which runs in a dorsal direction on the caudal aspect of the medial segmental vein to ventilate the cranial dorsal part of the medial segment (Sheets 4, 5 & 6). The cranial subsegmental bronchus (Mcr1) then passes in a lateral direction and gives off rami to ventilate the cranial, medial part of the segment at this level (Sheet 6, fig. 3).

The medial segmental bronchus (M) is now situated in the centre of the lobe slightly nearer the medial than the lateral border. It gives off a lateral bronchus (Ml1) (Sheet 6, fig. 5), and then approximately 3mm below the level at which the cranial subsegmental bronchus (Mcr1) arises, it gives off a bronchus which is known as the middle subsegmental bronchus (Mmid) from its medial aspect (Plate XLV). This bronchus (Mmid) runs in a ventral direction remaining at first nearer the medial than the lateral border of the lobe (Sheet 7 & 8); about 3mm from its origin, it gives off a medial ramus (Mmidm) which runs in a ventral and medial direction to ventilate the medial part of the lobe at this level (Plate XLV) (Sheet 8, figs. 3 - 6; Sheet 9, figs. 1 - 6; Sheet 10, figs. 1 - 4). The subsegmental bronchus then gives off further rami from its caudal/

caudal (Sheet 9, fig. 4), medial (Sheet 10, fig. 3), cranial (Sheet, 10, fig. 6) and lateral (Sheet 11, fig. 7) aspects; it becomes centrally situated in the lobe and can be traced to the ventral tip of the lobe (Plate XLV). (Sheets 12, 13 & 14). The middle subsegmental bronchus (Mmid), therefore, ventilates a middle subsegment of the medial segment.

Just below the level of origin of the middle subsegmental bronchus (Mmid), the segmental bronchus (M) gives off a second cranial subsegmental bronchus (Mcr2) (Plate XLV) (Sheet 7, fig. 6; Sheet 8, fig. 1). This bronchus runs in a cranial direction and, dividing into lateral and medial rami, ventilates the cranial part of the lobe at this level.

A further 3mm below this bronchus (Mcr2), the medial segmental bronchus (M) divides into a lateral (Ml) and a medial (Mmed) subsegmental bronchus (Plate XLV). These subsegmental bronchi run in a ventral direction diverging towards the lateral and medial borders of the lobe respectively and they extend to the ventral tip of the lobe; they give rise to several rami and it can be appreciated that they ventilate the lateral and medial subsegments in the cranial ventral part of the medial segment (Plate XLV) (Sheets 9 - 14).

In some lungs, the lateral broncho-pulmonary segment is not ventilated by a single bronchus as described above, but by two lateral bronchi given off by the lobar bronchus; the proximal bronchus (L1) ventilates an area which corresponds to the dorsal lateral part of the lateral segment, while the distal bronchus (L2) ventilates an area which corresponds to the ventral lateral part of the segment (Plate XXIX, fig. 1). In these cases/

cases, the proximal lateral bronchus ventilates an area which is known as the lateral segment, while the remainder of the lobe forms the medial segment.

The right intermediate lobar bronchus (I); this bronchus arises from the right main bronchus in common with the cardiac lobar bronchus (Plate XXVII). Nicolas & Dimitrova (1897) describe this bronchus as the first ventral bud developing from the stem bronchus ventral and caudal to the first collateral external branch (cardiac lobar bronchus). d'Hardiviller (1897) states that the intermediate lobar bronchus arises opposite to the cardiac lobar bronchus as an antero-internal bud from the stem bronchus, that is to say, by collateral branching. At first it is independent of the cardiac lobar bronchus, but soon it appears to be attached to it by an epithelial line. It later becomes attached to the base of the cardiac lobar bronchus and then it becomes obliquely attached to the bronchus. The writer has suggested that a more likely explanation is that, at first, the cardiac and intermediate lobar bronchi arise independently from the main bronchi, and then during their development they enlarge their openings and these conjoin.

The bronchus (I) runs in a ventral, caudal and medial direction to ventilate the intermediate lobe of the right lung (Plate XXVI). In most lungs the lobar bronchus gives rise to a segmental bronchus from its caudal aspect about 11mm from its origin. This bronchus (Id) runs horizontally in a caudal direction to ventilate the dorsal broncho-pulmonary segment of the/

the lobe and is known as the dorsal segmental bronchus. It gives off small dorsal, ventral and lateral subsegmental bronchi. (Plate XXVI, XXVII & XXXIV).

The lobar bronchus (I) continues as the ventral segmental bronchus (Iv) of the intermediate lobe. It gives off cranial subsegmental bronchi (Ivcr) which ventilate the cranial area of the lobe, and a caudal subsegmental bronchus (Ivca); the latter ventilates the caudal area of the lobe which lies just ventral to the dorsal segment; it forms the ventral wall of the foramen for the caudal vena cava and the dorsal part of the base of the lobe (Plate XXVII). The ventral segmental bronchus (Iv) is continued as the ventral subsegmental bronchus and ventilates the ventral part of the lobe (Plate XXVII).

The foramen for the caudal vena cava and the right phrenic nerve is formed therefore as follows: the lateral wall of the foramen is formed by the mediastinal surface of the diaphragmatic lobe, the dorsal part of the medial wall is formed by the dorsal segment and the ventral part of the medial wall is formed by the ventral segment.

<u>The right diaphragmatic lobar bronchus</u> (D) (right lower lobar bronchus); this bronchus is considered to be the continuation of the right main bronchus aftervit has given off the bronchi to the cardiac and intermediate lobes (Plate XXV, XXVI & XXVII). The diaphragmatic lobar bronchus is relatively much larger than the apical, cardiac and intermediate lobar bronchi; it follows a caudal and mainly horizontal course through the dorsal part of the diaphragmatic lobe. It does, however, incline slightly dorsally so that, at its termination, it is nearer/

nearer the dorsal surface than it is at its origin; furthermore, the terminal part of the bronchus inclines towards the mid-line. Several collateral bronchi arise from the diaphragmatic lobar bronchus: in its proximal part the bronchi are large and arise from the dorsal, ventral and ventral lateral aspects; these ventilate independent areas of lung tissue, broncho-pulmonary segments, and are called segmental bronchi. There are two dorsal, one ventral and two ventral lateral collateral bronchi ventilating the broncho-pulmonary segments. Arising from the lobar bronchus distal to the above, there are smaller collateral bronchi; these are numerous and varied, and although supplying smaller independent areas of lung tissue, are not considered to be segmental bronchi; instead, the continuation of the lobar bronchus, after the large collateral segmental bronchi have been given off, is considered to be a segmental bronchus.

The collateral segmental bronchi vary considerably in the order in which they arise from the lobar bronchus. In 75% of lungs examined, the first dorsal collateral bronchus (D1) arises proximal to the first ventral lateral branch (VL1) of the diaphragmatic lobar bronchus but distal to the cardiac (C) and intermediate (I) lobar bronchi (Plate XXX, fig. 1); however, in a few lungs, it may arise from the main bronchus at the same level as the cardiac and intermediate lobar bronchi or even proximal to them. In 12.5% of the lungs examined, the first dorsal bronchus (D1) arises from the diaphragmatic lobar bronchus at the same level as the first ventral lateral bronchus (Vl1) (Plate XXX, fig. 2), and in 12.5% of the cases, distal to/

to it (Plate XXX, fig. 3).

The first dorsal segmental bronchus (D1) runs in a dorsal direction, and it ventilates the cranial dorsal area of the diaphragmatic lobe which lies just caudal to the caudal dorsal part of the caudal broncho-pulmonary segment of the right apical lobe. This area of the diaphragmatic lobe is analogous to the apical broncho-pulmonary segment of the right lower lobe in the human lung, and the bronchus is analogous to the apical segmental bronchous. To avoid confusion this cranial dorsal area of the diaphragmatic lobe in the sheep is known as the apical broncho-pulmonary segment of the right diaphragmatic lobe, and the first dorsal segmental bronchus is known as the apical segmental bronchus.

The first ventral lateral bronchus arises just caudal to the first dorsal bronchus, but may arise at the same level as, or cranial to it. It runs in a caudal, ventral and lateral direction to ventilate the cranial ventral part of the diaphragmatic lobe which is analogous to the anterior basal broncho-pulmonary segment of the right lower lobe in the human; in the sheep, it is more appropriate to name it the ventral basal broncho-pulmonary segment of the right diaphragmatic lobe and the bronchus, the ventral basal segmental bronchus.

After the first dorsal (D1) and ventral lateral (VL1) bronchi have been given off, there is great variation in the order of origin of the succeeding bronchi. The second dorsal bronchus (D2) is the next to arise in 44%, the second ventral lateral bronchus (VL2) in 28%, and the ventral medial bronchus (VM) in 20% of the lungs examined. In the remaining 16% the second/

second dorsal bronchus (D2) is found to arise at the same level as either the second ventral lateral bronchus (VL2) or the ventral medial bronchus (VM).

The second dorsal bronchus (D2) ventilates the dorsal part of the diaphragmatic lobe which lies caudal to the apical broncho-pulmonary segment and is known as the subapical broncho-pulmonary segment of the right diaphragmatic lobe, the bronchus is known therefore as the subapical segmental bronchus.

The second ventral lateral bronchus (VL2) given off by the diaphragmatic lobar bronchus runs in a ventral, lateral & caudal direction to ventilate the area of the diaphragmatic lobe which lies just caudal to the ventral basal broncho-pulmonary segment. In the human lung, this area is known as the lateral basal segment of the right lower lobe, and as this nomenclature is quite appropriate in the sheep, this area is called the lateral basal broncho-pulmonary segment of the right diaphragmatic lobe, and the bronchus is called the lateral basal segmental bronchus.

In 52% of the lungs examined, the second dorsal (D2) and the second ventral lateral (VL2) arise at the same level, or succeed one another; in the remaining 48% of the lungs, the first ventral medial bronchus (VM) arises between them or at the same level as one of them. The relative positions of the three bronchi have been tabulated as follows:

<u>No. of lungs examined 50.</u>

VL2 → VM → D2	16%	(Plate XXX, fig. 4).
D2 → VM → VL2	20%	(" ", " 5).
VM → VL2 → D2	12%	(" ", " 6).

VM/

VM → D2 → VL2 8% (Plate XXX, fig. 7).

VL2 → D2 → VM 12% (" " , " 8).

D2 → VL2 → VM 16% (" " , " 9).

D2=VL2 → VM 4% (" " , " 10).

D2=VM → VL2 4% (" " , " 11).

D2 → VM=VL2 8% (" " , " 12).

<u>Example.</u> VL2 = VM; the second ventral lateral bronchus arises at the same level as the ventral medial bronchus.

VL2 → VM; the second ventral lateral bronchus arises proximal to the ventral medial bronchus.

/in which
In 72% of the lungs examined, the second dorsal bronchus arises distal to the second ventral lateral and the ventral medial bronchi, the first dorsal bronchus arises below the first ventral lateral bronchus.

In the lungs of the sheep which he examined, Narath (1901) has noted that the first dorsal bronchus arises at the same level as the first ventral lateral and is followed by the second ventral lateral and the second dorsal bronchi.

The ventral medial bronchus runs in a caudal, ventral and medial direction to ventilate an area on the mediastinal aspect of the diaphragmatic lobe which is known as the medial basal segment of the right diaphragmatic lobe. In the human lung, the medial basal segment has also been referred to as the cardiac segment and it is not analogous to this segment in the sheep.

The continuation of the lobar bronchus, after the above mentioned bronchi are given off, ventilates the caudal dorsal part/

part of the diaphragmatic lobe. In the human lung, the analogous area is termed the posterior basal broncho-pulmonary segment of the right lower lobe; but, in the sheep, it is more appropriate to name the segment, the dorsal basal broncho-pulmonary segment of the right diaphragmatic lobe, and the bronchus, the dorsal basal segmental bronchus.

The apical broncho-pulmonary segmental bronchus (A) of the right diaphragmatic lobe arises from the dorsal aspect of the lobar bronchus (D) and runs in a dorsal and slightly lateral direction (Plate XXV, XXVI, XXXI & XXXIV). About 5mm from its origin, the segmental bronchus gives off a medial sub-segmental bronchus (Am); this bronchus divides into cranial and caudal rami, and it ventilates the medial subsegment of the apical broncho-pulmonary segment which lies just dorsal to the lobar bronchus (Plate XXXIV). Approximately 5mm distal to the medial subsegmental bronchus, the segmental bronchus divides into a cranial (Acr) and a caudal (Aca) subsegmental bronchus. The cranial bronchus (Acr) runs at first in a dorsal direction and gives off a lateral bronchus (Acrl1); this bronchus runs in a dorsal and lateral direction and gives off smaller collateral rami which ventilate the lateral part of the cranial subsegment (Plate XXXI). The cranial bronchus then bends medially to run in a dorsal and medial direction giving off collateral rami from its cranial, caudal, lateral and medial aspects which ventilate the dorsal part of the cranial sub-segment (Plate XXXI & XXXIV). The caudal bronchus (Aca) runs in a caudal, dorsal and slightly medial direction to ventilate the/

the caudal subsegment. About 5mm from its origin, it gives off a lateral collateral bronchus (Acal) which runs in a caudal, dorsal and lateral direction, giving off smaller collateral rami to ventilate the caudal lateral part of the caudal subsegment (Plate XXXI & XXXIV). A short distance/distal to the lateral bronchus, a medial collateral bronchus (Acam) arises and runs in a caudal, dorsal and lateral direction (Plate XXXI & XXXIV). The caudal bronchus (Aca) then divides into dorsal and ventral bronchi which, in turn, divide into medial and lateral terminal rami; these give off small collateral rami and ventilate the caudal dorsal part of the apical broncho-pulmonary segment of the right diaphragmatic lobe (Plate XXV, XXXI & XXXIV).

The ventral basal broncho-pulmonary segmental bronchus (VB) of the diaphragmatic lobe arises from the ventral lateral aspect of the lobar bronchus (D) and runs in a caudal, lateral and ventral direction (Plate XXV, XXVI & XXXI). About 14mm from its origin, the segmental bronchus gives rise to a dorsal lateral subsegmental bronchus (VBl) from its dorsal lateral aspect (Plate XXXI). This dorsal lateral bronchus runs in a lateral and caudal direction, gives off small collateral rami from its cranial and caudal aspects and then divides into two bronchi, a ventral and a dorsal; the ventral bronchus continues to run in a lateral and caudal direction giving off small cranial, caudal, dorsal and ventral collateral rami, while the dorsal bronchus runs in a dorsal, lateral and caudal direction and also gives off small collateral rami. The dorsal lateral subsegmental/

subsegmental bronchus (VBl) ventilates the dorsal lateral subsegment of the ventral basal broncho-pulmonary segment. A short distance below the dorsal lateral bronchus, a medial subsegmental bronchus (VBm) arises from the ventral medial aspect of the segmental bronchus and runs in a lateral, caudal but more ventral direction to ventilate the medial subsegment of the ventral basal broncho-pulmonary segment (Plate XXXI). The medial subsegmental bronchus has several collateral rami arising from all its aspects before it divides into cranial and caudal bronchi. A distal lateral subsegmental bronchus may arise from the dorsal lateral aspect of the segmental bronchus (VB) before it divides into a cranial ventral (VBcr) and a caudal ventral (VBca) subsegmental bronchus approximately 26mm from its origin (Plate XXXI).

The cranial ventral bronchus (VBcr) runs in a ventral, lateral and slightly caudal direction to ventilate the cranial ventral subsegment of the ventral basal broncho-pulmonary segment. A short distance from its origin, the bronchus gives off a lateral collateral bronchus (VBcrl) which runs in a lateral direction and gives off small rami from its cranial, caudal, dorsal and ventral aspects. Just distal to this lateral ramus, a medial collateral bronchus (VBcrm) arises from its cranial medial aspect and runs in a lateral, ventral and cranial direction giving off small cranial, caudal, lateral and medial rami (Plate XXXI). Further cranial and caudal collateral bronchi arise from the cranial ventral subsegmental bronchus and give off smaller rami from their lateral, medial, cranial/

cranial and caudal aspects.

The caudal ventral bronchus (VBca) runs in a ventral, lateral and caudal direction to ventilate the caudal ventral subsegment of the ventral basal broncho-pulmonary segment (Plate XXXI). A lateral collateral bronchus (VBcal) is given off from the dorsal lateral aspect of the caudal bronchus close to its origin; this lateral bronchus runs in a caudal and lateral direction giving off small rami from its cranial, caudal, lateral and medial aspects (Plate XXXI). Just distal to the above mentioned lateral bronchus, a medial collateral bronchus (VBcam) is given off; this runs in a caudal, ventral and lateral direction giving off small rami from its cranial, caudal, lateral and medial aspects (Plate XXXI). The caudal ventral bronchus (VBca) then gives off further small collateral bronchi from its lateral, medial, cranial and caudal aspects.

The subapical broncho-pulmonary segmental bronchus (SA) arises from the dorsal aspect of the lobar bronchus (D) and runs in a caudal and dorsal direction (Plate XXV & XXVI). A short distance from its origin, the segmental bronchus gives rise to a medial subsegmental bronchus (SAm1) from its medial aspect. This bronchus (SAm1) runs in a medial, dorsal and caudal direction for about 4mm and then divides into dorsal and ventral bronchi; the dorsal bronchus runs in a dorsal, caudal and medial direction giving off small collateral rami from its dorsal, ventral, lateral and medial aspects; the ventral bronchus runs medially and then ventrally giving off rami from its dorsal, ventral, cranial and caudal aspects (Plate XXXIV). The/

The medial bronchus (SAm1) ventilates the medial subsegment of the subapical broncho-pulmonary segment. Approximately 5mm distal to the medial bronchus (SAm1), a lateral subsegmental bronchus (SAl1) arises from the lateral aspect of the segmental bronchus. This bronchus runs in a lateral and caudal direction to ventilate the cranial lateral subsegment of the subapical broncho-pulmonary segment; near its origin, it gives off a cranial bronchus which runs parallel to the segmental bronchus, and then it gives off small collateral rami from its dorsal, ventral, cranial and caudal aspects (Plate XXXII). About 5mm distal to the lateral subsegmental bronchus (SAl1), a second lateral subsegmental bronchus (SAl2) arises and runs in a caudal and lateral direction giving off small collateral rami from its dorsal, ventral, cranial and caudal aspects to ventilate the caudal lateral subsegment of the subapical broncho-pulmonary segment (Plate XXXII). A dorsal subsegmental bronchus (SAd) arises from the dorsal aspect of the segmental bronchus and runs in a caudal but more dorsal direction than the segmental bronchus; this dorsal bronchus divides into medial and lateral bronchi, and these give off smaller rami which ventilate the cranial dorsal subsegment of the subapical broncho-pulmonary segment (Plate XXXII & XXXIV). The continuation of the segmental bronchus (SA) is considered to be a subsegmental bronchus and it follows a caudal and dorsal course dividing into medial and lateral terminal bronchi; small collateral rami are given off from the medial, lateral, dorsal and ventral aspects of these terminal bronchi, and they ventilate the/

the caudal dorsal subsegment of the subapical broncho-pulmonary segment of the right diaphragmatic lobe (Plate XXXII & XXXIV).

The lateral basal broncho-pulmonary segmental bronchus (LB) of the right diaphragmatic lobe arises from the ventral lateral aspect of the lobarcbronchus (D), and it runs in a caudal, lateral and slightly ventral direction (Plate XXV, XXVI, XXVII & XXXII). Collateral subsegmental bronchi arise from the dorsal lateral, cranial and ventral aspects of the segmental bronchus, but caudal bronchi do not appear to arise from the segmental bronchus. Approximately 11mm from the origin of the segmental bronchus, the first **sub**segmental bronchus (LBm1) arises from its medial ventral aspect and runs in a caudal, lateral and ventral direction; it gives off small collateral rami from its dorsal, ventral and cranial aspects before dividing into cranial and caudal terminal rami (Plate XXXII). The medial subsegmental bronchus ventilates the medial subsegment of the lateral basal broncho-pulmonary segment. Just distal to the medial subsegmental bronchus, the first dorsal lateral subsegmental bronchus (LBl1) arises from the dorsal lateral aspect of the segmental bronchus. It runs in a lateral and caudal direction giving off a cranial and /a caudal collateral ramus before dividing into terminal cranial and caudal rami; these cranial and caudal rami give off small collateral branches from all their aspects. The dorsal lateral subsegmental bronchus (LBl1) ventilates the dorsal lateral subsegment of the lateral basal broncho-pulmonary segment. (Plate XXXII)/

XXXII). Approximately 6mm distal to the first lateral subsegmental bronchus (LB11), the second lateral subsegmental bronchus (LB12) arises and, like the first lateral subsegmental bronchus, it runs in a lateral and caudal direction giving off a cranial and a caudal collateral ramus; it then divides into cranial and caudal terminal rami which give off small collateral branches from all their aspects. The second lateral subsegmental bronchus (LB12) ventilates the lateral subsegment which lies just ventral to the subsegment ventilated by the subsegmental bronchus (LB11) (Plate XXXII).

A short distance distal to the second lateral subsegmental bronchus (LB12), the cranial ventral subsegmental bronchus (LBcr) arises and runs in a lateral and ventral direction, diverging from the segmental bronchus. Near its origin, it gives off dorsal lateral and ventral collateral rami, and then smaller collateral rami from its dorsal lateral, ventral, cranial and caudal aspects. The cranial ventral subsegmental bronchus ventilates the cranial ventral subsegment of the lateral basal broncho-pulmonary segment (Plate XXXII). Distal to the cranial ventral subsegmental bronchus (LBcr), the continuation of the lateral basal segmental bronchus may be considered to be the caudal ventral subsegmental bronchus (LBca) which ventilates the caudal ventral subsegment. It gives rise to collateral bronchi from its lateral, medial, cranial and caudal aspects, and finally it divides into a cranial and a caudal terminal bronchus. (Plate XXXII).

The medial basal broncho-pulmonary segmental bronchus (MB) of/

of the right diaphragmatic lobe arises from the ventral aspect of the lobar bronchus (D) and runs in a caudal and ventral direction (Plate XXVI, XXVII & XXXIV). About 5mm from its origin, the segmental bronchus (MB) gives off a ventral sub-segmental bronchus (MBv) which runs in a ventral direction and almost immediately divides into lateral and medial bronchi; these lateral and medial bronchi give off small collateral rami from all their aspects, and they ventilate the ventral subsegment of the medial basal broncho-pulmonary segment (Plate XXXIV). The next large subsegmental bronchus (MBd) arises from the dorsal aspect of the segmental bronchus. This bronchus runs in a caudal and horizontal direction to ventilate the dorsal subsegment of the medial basal broncho-pulmonary segment; it gives off small collateral dorsal, medial and lateral rami, and near its termination it also gives off ventral rami (Plate XXXIV). The continuation of the segmental bronchus runs in caudal direction giving off collateral rami from its ventral, lateral and medial aspects to ventilate the caudal subsegment of the segment (Plate XXVII & XXXIV).

The dorsal basal broncho-pulmonary segmental bronchus (DB) of the right diaphragmatic lobe is considered to be the continuation of the lobar bronchus (D), after it has given off the above mentioned segmental bronchi. The collateral rami of the segmental bronchus are numerous and varied; they arise from its dorsal, ventral, lateral and medial aspects to ventilate the various subsegments of the dorsal basal broncho-pulmonary segment (Plate XXV, XXVI, XXVII, & XXXIII). The proximal subsegmental bronchi are larger than the distal and they do

not/

not appear to arise from the segmental bronchus in any definite order. The lateral subsegmental bronchus (DBl1) may arise proximal or distal to the first dorsal subsegmental bronchus (DBd1); it runs in a ventral, lateral and caudal direction giving rise to smaller collateral bronchi from its dorsal lateral, ventral medial and cranial aspects. In its course and collateral branching this lateral subsegmental bronchus (DBl1) is very similar to the segmental bronchus (LB); it gives off the medial bronchus (DBl1m) and a lateral bronchus (DBl1l) and then bronchi from its cranial, caudal, lateral and medial aspects. It ventilates the cranial lateral subsegment of the dorsal basal broncho-pulmonary segment which adjoins the lateral basal segment (Plate XXXIII). The first dorsal subsegmental bronchus (DBd1) of the segmental bronchus is similar to the apical and subapical segmental bronchi in that, shortly after its origin, it gives off a collateral medial bronchus which ventilates the area of lung lying medial to the segmental bronchus, and then continues in a dorsal and caudal direction. Both the medial ramus and the dorsal continuation give off numerous small collateral rami from all their aspects and these ventilate the cranial dorsal subsegment of the dorsal basal pulmonary segment; this subsegment lies just caudal to the subapical broncho-pulmonary segment (Plate XXVI & XXXIII). In some lungs, the medial collateral bronchus of the subsegment -al bronchus (DBd1) may arise from the medial aspect of the segmental bronchus (Plate XXXIV); in others, there is no dorsal subsegmental bronchus (DBd1) arising from the segmental bronchus/

bronchus (DB), and instead it is given off as a dorsal collateral bronchus from the medial subsegmental bronchus (DBm1) which arises from the segmental bronchus.

From the ventral aspect of the segmental bronchus (DB) a subsegmental bronchus (DBv1) arises to run in a caudal and ventral direction, giving off medial and lateral collateral rami to ventilate the cranial ventral subsegment of the dorsal basal broncho-pulmonary segment which lies caudal to the medial basal segment (Plate XXVII & XXXIII). Small subsegment-al bronchi, which are similar as regards their course and branching to the subsegmental bronchi described above, arise from the dorsal, ventral, medial and lateral aspects of the segmental bronchus (DB); these collateral bronchi gradually decrease insize, and the areas which they ventilate become smaller. Near its termination, the segmental bronchus appears to divide dichotomously into medial (DBmt) and lateral (DBlt) terminal subsegmental bronchi which ventilate the medial and lateral caudal subsegments of the dorsal basal broncho-pulmonary segment by giving off collateral rami from their dorsal, ventral, medial and lateral aspects (Plate XXVII & XXXIII).

Left Lung.

The left lung is frequently described as having three lobes, an apical or upper lobe, a cardiac or middle (lingual) lobe and a diaphragmatic or lower lobe. However, an examination of the bronchial tree will reveal that an area of the left lung comprising the apical and cardiac lobes is ventilated by the first ventral lateral collateral bronchus arising from the ventral/

ventral lateral aspect of the left main bronchus about 16mm from the bifurcation of the trachea. This bronchus divides into two bronchi, a cranial one which ventilates the area of the left lung usually described as the apical lobe, and a ventral lateral one which ventilates the area usually described as the cardiac lobe. According to Narath (1901) this arrangement of the first ventral lateral bronchus on the left side is characteristic of the artiodactyls.

It would appear to be more accurate to consider the left lung as consisting of two lobes, an apical-cardiac or upper lobe and a diaphragmatic or lower lobe. If the first ventral lateral collateral bronchus of the left main bronchus is considered to be a lobar bronchus ventilating the apical-cardiac lobe, then the cranial and the ventral lateral bronchi into which it divides must be considered to be broncho-pulmonary segmental bronchi ventilating broncho-pulmonary segments. The cranial area of the apical-cardiac lobe can be identified as the area frequently named the apical lobe, and it is best described as being the apical broncho-pulmonary segment of the apical-cardiac lobe of the left lung, the ventral lateral area of the apical-cardiac lobe likewise being identifiable as the area frequently called the cardiac lobe, and it is best described as being the cardiac broncho-pulmonary segment of the apical-cardiac lobe of the left lung.

The continuation of the left main bronchus, distal to the point at which the apical-cardiac lobar bronchus arises, is considered to be the lobar bronchus ventilating the diaphragmatic lobe/

lobe of the left lung.

The apical-cardiac lobar bronchus (AC): this arises from the ventral lateral aspect of the left main bronchus approximately 16mm from the bifurcation of the trachea; it runs in a ventral, lateral and slightly caudal direction for a distance of 10mm, usually in a subpleural position, when it divides into two segmental bronchi, the apical broncho-pulmonary segmental bronchus (ACa) and the cardiac broncho-pulmonary segmental bronchus (ACc) (Plate XXVI, XXVII, XXXV & XXXVI).

The apical segmental bronchus (ACa) runs at first in a lateral direction and then curves cranially to run in a cranial and slightly dorsal direction; it is subpleural in position for approximately the first 10mm of its length. Several subsegmental bronchi arise from the segmental bronchus. The first bronchus arises from the convexity of the segmental bronchus as it curves to run in a cranial direction. This lateral subsegmental bronchus (ACal1) runs in a lateral and slightly caudal direction for approximately 4mm when it divides into two rami, a dorsal and a ventral; the dorsal ramus runs in a caudal and lateral direction and gives off smaller collateral rami; the ventral ramus runs in a ventral, lateral and slightly caudal direction and also gives off small rami. The lateral subsegmental bronchus (ACal1) ventilates the caudal subsegment of the apical broncho-pulmonary segment and is known as the caudal subsegmental bronchus (Plate XXXVI). The next subsegmental bronchus usually arises from the dorsal lateral aspect of the apical segmental bronchus. This dorsal subsegmental/

subsegmental bronchus (ACad1) runs in a dorsal, lateral and cranial direction for a short distance when it gives off a caudal ramus; this ramus runs in a caudal and slightly dorsal direction and gives off small collateral rami from its lateral, medial, dorsal and ventral aspects. The bronchus (ACad1) continues to run in a dorsal and cranial direction giving off collateral rami from its lateral, medial, cranial and caudal aspects; it ventilates the caudal dorsal subsegment of the apical broncho-pulmonary segment (Plate XXXVI).

A lateral ventral subsegmental bronchus (ACav1) may arise proximal to the dorsal subsegmental bronchus (ACad1), but it more often arises distal to it. This ventral bronchus (ACav1) runs in a ventral, lateral and cranial direction giving off small collateral rami from its cranial, caudal, lateral and medial aspects, and it ventilates the ventral subsegment of the apical broncho-pulmonary segment which forms part of the cardiac notch between the apical and cardiac broncho-pulmonary segments (Plate XXXVI).

Distal to these bronchi described above, dorsal, ventral and medial subsegmental bronchi arise from the segmental bronchus. They give off smaller collateral rami and ventilate the dorsal and ventral parts of the apical broncho-pulmonary segment. The terminal part of the segmental bronchus may be considered to be a subsegmental bronchus which ventilates the apical subsegment of the segment. (Plate XXXVI).

The cardiac broncho-pulmonary segmental bronchus (ACc) runs, from its point of origin, in a ventral and lateral direction/

direction to ventilate the cardiac broncho-pulmonary segment (Plate XXVI & XXXVI). For the first thirty millimetres of its length, it lies subpleural in position on the medial aspect of the lobe.

Generally, the first subsegmental bronchus (ACcl1) arises from the cranial lateral aspect of the segmental bronchus approximately 10mm from its origin; this cranial lateral bronchus runs in a ventral, lateral and cranial direction giving off small rami. It ventilates the dorsal, cranial lateral subsegment of the cardiac segment which forms the cardiac notch with the ventral and caudal subsegments of the apical segment (Plate XXXVI).

The second subsegmental bronchus (ACcl2) usually arises from the caudal lateral aspect of the segmental bronchus a short distance below the bronchus (ACcl1), and it runs in a ventral, lateral and caudal direction giving off collateral rami to ventilate the dorsal, caudal lateral subsegment (Plate XXXVI). In some lungs, these two subsegmental bronchi arise from a common lateral subsegmental bronchus given off by the segmental bronchus, and they are then recognised as the cranial and caudal rami of this subsegmental bronchus (Plate XXXV).

The segmental bronchus continues to give off subsegmental bronchi from its cranial lateral and caudal lateral aspects; near its termination, the segmental bronchus may be considered to continue as a ventral subsegmental bronchus (ACcv) which gives off collateral rami from its cranial, caudal, lateral and medial aspects to ventilate the ventral subsegment (Plate XXXVI).

The/

The cranial and caudal subsegmental bronchi which usually arise independently at the same level may be found arising from a common bronchus in some lungs.

<u>The left diaphragmatic lobar bronchus</u> (D) (left lower lobar bronchus): it is considered to be the continuation of the left main bronchus after it has given off the apical-cardiac lobar bronchus (AC) (Plate XXXV). The left diaphragm-atic lobar bronchus gives off several collateral bronchi; the first of these bronchi are the largest and arise from the dorsal, ventral and ventral lateral aspects of the lobar bronchus. They ventilate independent areas of the left diaphragmatic lobe which are broncho-pulmonary segments, and therefore, they are named broncho-pulmonary segmental bronchi. Distal to these large collateral bronchi, smaller collateral bronchi arise from the dorsal, ventral, ventral lateral and medial aspects of the lobar bronchus, and these ventilate small independent areas of lung tissue, but they are not designated segmental bronchi because the continuation of the lobar bronchus, beyond the point at which the large collateral bronchi are given off, is considered to be a broncho-pulmonary segmental bronchus (Plate XXXV).

In the left lung, there is little variation in the order in which the segmental bronchi arise from the diaphragmatic lobar bronchus. In 83% of the lungs examined, the order is as follows: the first bronchus arises from the dorsal aspect of the lobar bronchus, the second just distal to the first from the ventral lateral aspect, the third arises from the dorsal aspect/

aspect, while the fourth arises from the ventral aspect of the lobar bronchus just proximal to the fifth bronchus which arises from the ventral lateral aspect; distal to this point, the continuation of the lobar bronchus is considered to be a segmental bronchus. In 17% of the lungs examined, there is no ventral bronchus arising from the ventral aspect of the lobar bronchus; in these cases, the corresponding area of lung tissue is ventilated by a collateral ramus given off from the distal ventral lateral segmental bronchus. The above bronchi arising from the diaphragmatic lobar bronchus ventilate large independent areas of lung tissue and therefore are designated segmental bronchi which ventilate broncho-pulmonary segments.

The first dorsal bronchus ventilates the cranial dorsal area of the diaphragmatic lobe which lies just dorsal to the caudal part of the apical broncho-pulmonary segment of the apical-cardiac lobe; it is analogous to the apical segmental bronchus in the human lung which ventilates the apical broncho-pulmonary segment, and as this terminology is quite appropriate in the sheep lung, the first dorsal bronchus will be known as the apical broncho-pulmonary segmental bronchus (A) and the area ventilated by it, the apical broncho-pulmonary segment of the left diaphragmatic lobe (Plate XXVI & XXXV).

After the apical segmental bronchus (A), the first ventral lateral bronchus arises from the left diaphragmatic lobar bronchus (D). This bronchus ventilates the cranial ventral part of the left diaphragmatic lobe which lies just caudal to the cardiac broncho-pulmonary segment of the apical-cardiac lobe/

lobe. In the human lung, this area is known as the anterior basal broncho-pulmonary segment of the left lower lobe and is ventilated by the anterior basal segmental bronchus. In the sheep lung this nomenclature is not appropriate, and the area will be known as the ventral basal broncho-pulmonary segment and the bronchus as the ventral basal segmental bronchus (VB). (Plate XXVI, XXVII,& XXXV).

The second dorsal bronchus arising from the left diaphragmatic lobar bronchus (D) ventilates a dorsal area of the left diaphragmatic lobe which lies just caudal to the area ventilated by the apical segmental bronchus (A). There is no analogy to be drawn in the human lung with regard to this bronchus, and the area will be known as the subapical broncho-pulmonary segment of the left diaphragmatic lobe; the bronchus ventilating it will be known as the subapical segmental bronchus (SA). (Plate XXVI & XXXV).

The ventral segmental bronchus, arising from the ventral aspect of the left diaphragmatic lobar bronchus (D) just distal to the above, ventilates an area on the mediastinal aspect of the left diaphragmatic lobe. This bronchus also has no analogy in the human lung and will be known as the medial basal segmental bronchus (MB), while the area which it ventilates will be known as the medial basal broncho-pulmonary segment of the left diaphragmatic lobe. (Plate XXVII, & XL).

The second ventral lateral bronchus of the left diaphragmatic lobe arises just distal to the medial basal segmental bronchus, and it ventilates an area of the diaphragmatic lobe which/

which lies caudal to the ventral basal segment. It is analogous to the lateral basal segmental bronchus of the left lower lobe in the human lung which ventilates the lateral basal broncho-pulmonary segment. In the sheep, this nomenclature is appropriate, and the second ventral lateral bronchus will be known as the lateral basal segmental bronchus (LB) and the area as the lateral basal broncho-pulmonary segment. (Plate XXVI & XXXV).

The continuation of the lobar bronchus, after the above bronchi are given off, is considered to be a segmental bronchus, and it ventilates the caudal area of the left diaphragmatic lobe. It is analogous to the posterior basal segmental bronchus in the human lung which ventilates the posterior basal broncho-pulmonary segment of the left lower lobe. In the sheep, the nomenclature in use in the human lung is not appropriate, and the bronchus will be known as the dorsal basal segmemtal bronchus (DB), and the area which it ventilates will be known as the dorsal basal broncho-pulmonary segment. (Plate XXVI, XXVII, XXXV & XL).

The apical broncho-pulmonary segmental bronchus (A) of the left diaphragmatic lobe arises from the dorsal aspect of the lobar bronchus (D), just distal to its origin, and runs in a dorsal, caudal and lateral direction for about 10mm when it divides into two subsegmental bronchi, a cranial (Acr) and a caudal (Aca) (Plate XXXV & XXXVI). The cranial bronchus (Acr) runs at first in a lateral and dorsal direction, and then it bends cranially to run in a cranial and dorsal direction; collateral/

collateral rami arise from its dorsal, ventral, lateral and medial aspects and these in their turn give off small collateral rami. The cranial bronchus (Acr) ventilates the cranial dorsal subsegment of the apical broncho-pulmonary segment; the size of the subsegment depends on the size of the apical segment of the apical-cardiac lobe and more directly on the size of the subsegment ventilated by the first dorsal subsegmental bronchus (ACad1) of the apical segmental bronchus (ACa) (Plate XXXVI). The caudal subsegmental bronchus (Aca) of the apical broncho-pulmonary segment of the left diaphragmatic lobe runs in a caudal and dorsal direction to ventilate the caudal subsegment of the apical segment. It gives off a large medial bronchus (Acam) followed by several collateral rami which arise from its dorsal, ventral, lateral and medial aspects; all these collateral rami give off smaller collateral rami (Plate XXXVI). In some lungs the segmental bronchus gives off a medial subsegmental bronchus before it divides into cranial and caudal bronchi; in these cases, the medial bronchus ventilates the area which is usually ventilated by the medial ramus (Acam) of the bronchus (Aca).

The ventral basal segmental bronchus (VB) arises from the ventral lateral aspect of the diaphragmatic lobar bronchus (D), a short distance distal to the apical segmental bronchus (A) (Plate XXXV). This bronchus runs in a ventral, lateral and caudal direction for approximately 8mm when it gives off a subsegmental bronchus from its medial ventral aspect; this medial subsegmental bronchus (VBm) runs in a ventral direction and/

and ventilates the medial subsegment of the segment (Plate XXXVII). Just distal to the point at which the bronchus (VBm) arises, a subsegmental bronchus is given off by the segmental bronchus from its dorsal lateral aspect. This dorsal lateral subsegmental bronchus (VBl) runs in a lateral direction for approximately 5mm when it divides into two rami, a dorsal and a ventral; these dorsal and ventral rami diverge, running in a lateral and slightly caudal direction, and give off small collateral rami. The subsegmental bronchus (VBl) ventilates the dorsal lateral subsegment of the ventral basal segment. (Plate XXXVII).

Arising from the cranial aspect of the segmental bronchus (VB), just distal to the lateral subsegmental bronchus (VBl), a cranial ventral subsegmental bronchus (VBcr) runs in a ventral and slightly cranial direction to ventilate the cranial ventral subsegment of the ventral basal broncho-pulmonary segment. Several small collateral rami arise from the cranial, caudal, lateral and medial aspects of this subsegmental bronchus. (Plate XXXVII).

The continuation of the segmental bronchus (VB) is considered to be the caudal ventral subsegmental bronchus (VBca) which ventilates the caudal ventral subsegment of the ventral basal segment (Plate XXXVII). A small medial bronchus (VBcam) arises from the ventral medial aspect of the bronchus (VBca) a short distance from its origin, and about the same level, a lateral bronchus (VBcal) arises from its dorsal lateral aspect. Just distal to these bronchi, the subsegmental bronchus (VBca) gives/

gives off a bronchus (VBcacr) from its cranial aspect; this bronchus runs in a ventral, lateral and slightly cranial direction to ventilate the cranial area of the caudal ventral subsegment, and it gives off a number of small rami from its cranial, caudal, lateral and medial aspects. The caudal ventral subsegmental bronchus (VBca) continues in a caudal, ventral and lateral direction giving off progressively smaller bronchi from its cranial, caudal, lateral and medial aspects. (Plate XXXVII).

The subapical broncho-pulmonary segmental bronchus (SA) arises from the dorsal aspect of the diaphragmatic lobar bronchus (D) at a point approximately 10mm distal to the point at which the apical segmental bronchus (A) arises (Plate XXVI, XXXV & XL). The bronchus (SA) runs in a caudal and dorsal direction to ventilate the dorsal area of the diaphragmatic lobe which lies caudal to the apical broncho-pulmonary segment; it is known as the subapical broncho-pulmonary segment. Subsegmental bronchi are given off by the segmental bronchus (SA), at first, from its lateral and medial aspects, and later, from its dorsal aspect. The first subsegmental bronchus (SAm1) arises from the medial aspect of the segmental bronchus; it runs in a ventral, medial and slightly caudal direction to ventilate the medial subsegment of the subapical segment (Plate XXXVII & XL). The second subsegmental bronchus (SAl1) arises from the lateral aspect of the segmental bronchus (SA) and runs in a lateral and slightly caudal direction giving off smaller collateral rami; it ventilates the cranial lateral subsegment/

subsegment of the subapical segment which lies dorsal to the lateral basal broncho-pulmonary segment (Plate XXXVII). The succeeding subsegmental bronchi ventilate the lateral and cranial dorsal subsegments, while the terminal subsegmental bronchus ventilates the caudal dorsal subsegment of the subapical segment (Plate XXXVII & XL).

The medial basal segmental bronchus (MB) arises from the ventral aspect of the lobar bronchus (D) (Plate XXVII & XL). It lies just distal in position to the subapical segmental bronchus (SA) and just proximal to the lateral basal segmental bronchus (LB). This bronchus (MB) runs in a caudal and ventral direction to ventilate the medial basal segment of the left diaphragmatic lobe which may be described as being cranial, ventral and mediastinal in position. As in the right lung, the segmental bronchus (MB) gives off collateral subsegmental bronchi (MBv & MBd) from its ventral and dorsal aspects, and is then continued as the caudal subsegmental bronchus (Plate XL).

The lateral basal segmental bronchus (LB) arises from the ventral lateral aspect of the lobar bronchus (D) and runs in a ventral, lateral and caudal direction (Plate XXVI, XXVII & XXXV). Approximately 6mm from its origin, the bronchus (LB) gives off a medial subsegmental bronchus (LBm1) from its medial ventral aspect (Plate XXXVIII). This bronchus (LBm1) runs in a ventral, caudal and slightly lateral direction to ventilate the subsegment which lies on the medial aspect of the segment lateral to the medial basal segment; it gives off several small/

small collateral rami from its lateral, medial, dorsal and ventral aspects. Just distal to the point of origin of the bronchus (LBm1), a second subsegmental bronchus arises from the dorsal lateral aspect of the segmental bronchus (Plate XXXVIII). This dorsal lateral subsegmental bronchus (LBl1) runs in a caudal and lateral direction for a short distance when it divides into two bronchi, a cranial and a caudal; the cranial bronchus runs in a lateral direction giving off small collateral rami, while the caudal bronchus runs in a lateral and caudal direction and gives off collateral rami. The subsegmental bronchus (LBl1) ventilates the dorsal lateral subsegment of the lateral basal broncho-pulmonary segment.

Approximately 10mm below the point at which it gives off this lateral bronchus (LBl1), the segmental bronchus gives off a large cranial ventral subsegmental bronchus (LBcr) from its cranial aspect (Plate XXXVIII). This bronchus (LBcr) runs in a lateral and ventral, but less caudal direction than the parent bronchus; collateral bronchi arise from its dorsal, ventral, cranial and caudal aspects. The cranial ventral subsegment of the lateral basal segment is ventilated by this bronchus (LBcr).

At approximately the same level as the segmental bronchus (LB) gives off the cranial ventral subsegmental bronchus (LBcr), it gives rise to a second lateral subsegmental bronchus (LBl2) from its dorsal lateral aspect. This bronchus (LBl2) is smaller than the lateral bronchus (LBl1) and, running in a lateral direction, it gives off a number of rami which ventilate a lateral subsegment (Plate XXXVIII).

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The continuation of the segmental bronchus (LB) is considered to be the caudal ventral subsegmental bronchus (LBca) (Plate XXXVIII); this runs in a caudal, lateral and ventral direction to ventilate the caudal ventral subsegment of the lateral basal segment. It gives off several rami from its cranial, caudal, lateral and medial aspects and then divides into cranial and caudal terminal bronchi.

As in the right lung, the continuation of the diaphragmatic lobar bronchus (D), distal to the point at which the last of the above segmental bronchi arise, is considered to be the segmental bronchus (DB) which ventilates the dorsal basal broncho-pulmonary segment of the left diaphragmatic lobe (Plate XXVI, XXVII & XXXV). This bronchus (DB) gives off several subsegmental bronchi from its dorsal, ventral, lateral and medial aspects which ventilate the subsegments of the dorsal basal segment; the order in which these bronchi arise varies, and the proximal bronchi are larger than the distal. (Plate XXXV, XXXIX & XL).

The first dorsal subsegmental bronchus (DBd1) arises from the dorsal aspect of the segmental bronchus, and it runs in a caudal and dorsal direction to ventilate the cranial dorsal subsegment of the dorsal basal segment which lies just caudal to the subapical broncho-pulmonary segment. It gives off collateral bronchi from its lateral and medial aspects and, in addition, towards its termination, collateral rami from its dorsal aspect. In its course and branching this bronchus (DBd1) is very similar to the subapical segmental bronchus (SA) (Plate/

(Plate XXXIX & XL).

A ventral subsegmental bronchus (DBv1) arises from the ventral aspect of the segmental bronchus a short distance from its origin. This bronchus (DBv1) runs in a caudal and ventral direction, giving off small collateral rami from its lateral, medial, dorsal and ventral aspects; it ventilates the cranial·ventral subsegment of the dorsal basal segment which lies just caudal to the medial basal segment. (Plate XXXIX & XL).

The first lateral subsegmental bronchus (DBl1) arises from the ventral lateral aspect of the segmental bronchus in close proximity to the above mentioned bronchi. This bronchus (DBl1) runs in a ventral, lateral and caudal direction to ventilate the cranial lateral subsegment of the dorsal basal segment; it gives off several collateral rami which are very similar to the collateral rami given off by the lateral basal segmental bronchus (Plate XXXVIII). A medial bronchus (DBl1m) arises from the ventral medial aspect and a lateral bronchus (DBl1l) arises from the dorsal lateral aspect of the bronchus (DBl1); after these bronchi, cranial, caudal, lateral and medial bronchi are given off.

Other subsegmental bronchi arise from the dorsal, ventral, lateral and medial aspects of the segmental bronchus (DB). These bronchi become smaller towards the termination of the bronchus which finally divide into medial (DBmt) and lateral (DBlt) terminal subsegmental bronchi; these bronchi give off several smaller bronchi and ventilate the medial and lateral caudal/

caudal subsegments of the dorsal basal segment. (Plate XXVII, XXXIX & XL).

To summarise, from a survey carried out on fifty lungs by means of dissections and corrosion casts, and by serial sections of the right cardiac lobe of one of these, it is evident that, although numerous variations do occur in the ramifications of the bronchial tree, it is possible to recognise a general scheme.

The trachea and main bronchi give rise to lobar bronchi which ventilate those large independent areas of the lung known as lobes. Arising from the lobar bronchi there are large bronchi which ventilate the independent areas of a lobe known as broncho-pulmonary segments, and these are called segmental bronchi. The segmental bronchi give rise to bronchi which ventilate large independent areas within a segment known as subsegments, and these bronchi are known as subsegmental bronchi.

The bronchi have been named according to the size of the area which they ventilate and according to the position of this area within the larger area of which they are a part.

In the right lung, the right apical lobe is always ventilated by a lobar bronchus which arises from the trachea; this bronchus then divides into two bronchi which ventilate the cranial and caudal broncho-pulmonary segments of the lobe. The further branching of these bronchi may vary but the above findings are constant. The cardiac and intermediate lobar bronchi arise from a common opening in the ventral lateral aspect/

aspect of the right main bronchus. In most lungs, the cardiac lobar bronchus subsequently gives off a lateral bronchus which ventilates the lateral segment of the lobe, and it is then continued as the medial segmental bronchus which ventilates the medial segment. In a few lungs, there are two lateral bronchi ventilating the area which is normally ventilated by the lateral segmental bronchus with the result that the lateral segment is reduced in size and the medial segment is correspondingly increased. The intermediate lobar bronchus gives off a dorsal bronchus from its caudal aspect, and this ventilates the dorsal segment while the lobar bronchus continues as the ventral segmental bronchus ventilating the ventral segment. After it has given rise to the cardiac and intermediate bronchi, the main bronchus is known as the diaphragmatic lobar bronchus. It gives rise to a number of smaller bronchi which ventilate the various segments of the lobe. The order in which these segmental bronchi arise varies considerably, but the number of bronchi present is always constant. Two bronchi arise from the ventral lateral aspect of the lobar bronchus to ventilate the ventral basal and lateral basal segments. Two bronchi arise from the dorsal aspect to ventilate the apical and subapical segments, and one bronchus arises from the ventral aspect to ventilate the medial basal segment. Distal to the point at which it gives off the above bronchi, the diaphragmatic lobar bronchus is known as the dorsal basal segmental bronchus, and it ventilates that remaining area of the lobe known as the dorsal basal segment.

In/

In the left lung, the main bronchus gives off a bronchus from its ventral lateral aspect about 16mm below the bifurcation of the trachea. This bronchus ventilates the apical-cardiac lobe and divides into two bronchi which ventilate the apical and cardiac segments of the lobe. The continuation of the left main bronchus is known as the diaphragmatic lobar bronchus, and it gives off several smaller bronchi which ventilate the segments of the lobe. There is much less variation in the order in which these bronchi arise from the lobar bronchus in the left lung, but otherwise they are similar in number and position to their counterparts in the right lung. After it has given off the segmental bronchi, the diaphragmatic lobar bronchus is known as the dorsal basal segmental bronchus, and it ventilates the dorsal basal segment.

Description of the Pulmonary Arteries.

A survey of the pulmonary arteries was carried out on the lungs of fifteen sheep by means of dissections, corrosion casts and serial sections of the right cardiac lobe of one of these. In the following description the arteries are described with reference to the areas of the lung which they supply and to their position in relation to the bronchi. It must be remembered that these areas also receive some blood from the bronchial arteries.

In the sheep lung as in the human lung, it may be said that the pulmonary artery and its branches generally follow the bronchi very closely. However, it has been noted by Appleton (1944) in the human lung and by Narath (1901) in the lungs of artiodactyls/

artiodactyls that, in the region of the hilus, there is a deviation in the branching of the arteries from that of the bronchial tree; Narath has observed that in the lungs of artiodactyls arteries which arise from the pulmonary artery at different points sometimes accompany the branches of the single bronchus, and conversely Appleton (1945) has noted that in the human the branches of the same artery sometimes accompany bronchi with different origins from the bronchial tree. In the human lung, Melnikoff (1924) has observed that although arteries may vary in their origin, they still supply the same areas of the lung. Examples of similar deviations in the sheep are referred to during the following description of the arteries.

The pulmonary artery arises from the conus arteriosus of the right ventricle where it is related cranially to the right auricle, caudally to the left auricle and medially to the aorta. It curves dorsally, caudally and medially, and lying caudal to the arch of the aorta it divides into right and left pulmonary arteries which carry the blood to the right and left lungs respectively. In the first part of its course the pulmonary artery is enveloped in a common sheath with the aorta; this common sheath is derived from the visceral layer of the serous pericardium. Just cranial to the point at which the artery bifurcates into right and left arteries it is connected to the aorta by a band of fibrous tissue; this is the remnant of the ductus arteriosus which is a vessel connecting the pulmonary artery to the aorta in the foetus.

The/

The artery is bulbous at its origin where it forms three pouches, the sinuses of the pulmonary artery, and these correspond to and lie just distal to the cusps of the pulmonary valve. The artery gradually decreases in calibre towards its bifurcation.

Right Pulmonary Artery.

The bifurcation of the pulmonary artery lies slightly to the left of the mid-line, with the result that the right pulmonary artery is slightly longer than the left; it passes dorsal to the left atrium of the heart and ventral to the bifurcation of the trachea to reach the hilus of the right lung. It enters the lung ventral to the right main bronchus. As the right pulmonary artery passes ventral to the trachea, it gives off a branch which runs in a cranial direction and passing obliquely under the trachea carries the blood to the apical lobe of the right lung. This branch of the right pulmonary artery will be known as the right apical lobar artery.

The right apical lobar artery: this divides into two branches, a cranial and a caudal, which carry the blood to the cranial and caudal broncho-pulmonary segments of the right apical lobe respectively. These rami will be referred to as the cranial and caudal segmental arteries of the right apical lobe. (Plate XLII).

The cranial segmental artery passes in a cranial and lateral direction to reach the ventral medial aspect of the cranial broncho-pulmonary segmental bronchus (Cr), just distal to the point at which the apical subsegmental bronchus (Cra) arises/

arises. A ramus which may be termed the apical subsegmental artery is given off by the segmental artery; this artery follows the dorsal medial aspect of the apical subsegmental bronchus (Cra) giving off small rami which usually follow the cranial borders of the dorsal, ventral and medial collateral bronchi arising from the subsegmental bronchus (Plate XLI, XLII & XLIII).

The cranial segmental artery follows the cranial medial border of the segmental bronchus (Cr) and gives off a ramus which will be referred to as the cranial lateral subsegmental artery; this latter artery passes over the lateral aspect of the ventral subsegmental bronchus (Crv) and follows the cranial lateral border of the cranial lateral subsegmental bronchus (Crl). Small rami arise from it and these correspond to the collateral bronchi given off by the cranial lateral subsegmental bronchus. (Plate XLI, XLII & XLIII).

Distal to the point at which it has given off the apical subsegmental and cranial lateral subsegmental arteries, the cranial segmental artery may be termed the ventral subsegmental artery because it carries blood to the ventral subsegment of the cranial broncho-pulmonary segment; it runs along the dorsal medial border of the ventral subsegmental bronchus (Crv) and gives off small rami which correspond to the collateral and terminal rami which arise from the subsegmental bronchus. (Plate XLI, XLII & XLIII).

The caudal segmental artery of the right apical lobe runs in a dorsal, lateral and slightly cranial direction towards the caudal/

caudal lateral subsegmental bronchus (Cal). At a point medial to this bronchus, the artery divides into two rami, a subapical subsegmental artery which runs in a dorsal direction to meet the subapical subsegmental bronchus (Casa), and a caudal lateral subsegmental artery which accompanies the caudal lateral subsegmental bronchus (Cal). (Plate XLI, XLII & XLIII).

The subapical subsegmental artery follows the dorsal medial border of the subapical subsegmental bronchus (Casa) and gives off rami which correspond to and accompany the collateral rami of the bronchus. It is interesting to note that the artery which accompanies the first dorsal collateral ramus (Casad) of the subapical subsegmental bronchus usually arises from the subapical subsegmental artery, but in some lungs it arises from the apical subsegmental artery given off by the cranial segmental artery (Plate XLIV, fig. 2). This illustrates that the observations made with regard to the pulmonary artery in the human lung by Appleton (1945) and Melnikoff (1924) also apply in the sheep lung.

The caudal lateral subsegmental artery runs along the cranial medial border of the caudal lateral subsegmental bronchus (Cal) until near the termination of the bronchus, when the artery becomes caudal lateral in position. It gives off small rami which accompany the cranial, caudal, lateral and medial collateral rami given off by the subsegmental bronchus. (Plate XLIII).

To summarise, the de-oxygenated blood which is destined for/

for the apical lobe of the right lung is carried there by a ramus of the right pulmonary artery known as the right apical lobar artery. This lobar artery arises from the right pulmonary artery before the latter has reached the hilus of the lung, and it soon divides into two rami, a cranial and a caudal; the cranial ramus which is known as the cranial segmental artery carries the blood to the cranial broncho-pulmonary segment of the right apical lobe, while the caudal ramus which is known as the caudal segmental artery carries the blood to the caudal broncho-pulmonary segment of the right apical lobe.

The right pulmonary artery enters the lung ventral to the right main bronchus, and then it curves round the cranial border of the cardiac lobar bronchus to reach the lateral aspect of the diaphragmatic lobar bronchus (Plate XLI & XLII). As it curves round the cardiac lobar bronchus, the right pulmonary artery gives off two rami; the first runs in a caudal direction, carrying blood to the intermediate lobe of the right lung, and is known as the intermediate lobar artery, while the second or distal ramus runs in a caudal and lateral direction, carrying blood to the right cardiac lobe, and is known as the right cardiac lobar artery (Plate XLII).

<u>The right intermediate lobar artery</u>: this arises from the right pulmonary artery as the latter crosses the ventral aspect of the right main bronchus, and it runs in a caudal and nearly horizontal direction to meet the intermediate lobar bronchus (I). The artery accompanies the bronchus lying/

lying on its lateral ventral aspect, and it gives off a dorsal segmental artery which accompanies the dorsal segmental bronchus (Id) lying on its lateral aspect (Plate XLI & L). The artery continues as the ventral segmental artery and, lying on the lateral aspect of the ventral segmental bronchus (Iv), it gives off subsegmental arteries which accompany the subsegmental bronchi (Plate XLI & L).

It is interesting to note that, although the right cardiac and intermediate lobar bronchi arise from a common opening in the right main bronchus, the intermediate lobar artery and the right cardiac lobar artery are given off independently by the right pulmonary artery (Plate XLII). This shows that the findings of Narath (1901) and Appleton (1944), with regard to the arrangement of the arteries at the hilus, apply in the sheep lung.

<u>The right cardiac lobar artery</u>: this artery lies in a subpleural position on the cranial aspect of the lobar bronchus. On the level at which the lateral segmental bronchus (L) arises from the lobar bronchus (C), the lobar artery gives off a ramus which runs in a lateral and slightly dorsal direction to reach the medial aspect of the dorsal subsegmental bronchus (Ld) (Plate XLV) (Sheet 1, figs. 1 - 6). The lobar artery now becomes slightly separated from the bronchus (C), although it still lies in a subpleural position on the cranial aspect of the bronchus and on the caudal aspect of the right cardiac vein (Sheet 1, figs. 7, 8 & 9). Approximately 2mm below the level at which it gives off the first small lateral artery, the lobar/

lobar artery gives off a second lateral artery which supplies most of the blood to the lateral broncho-pulmonary segment, and therefore, it is known as the lateral segmental artery (Plate XLV). It runs in a lateral direction on the cranial aspect of the lateral segmental bronchus (L) and gives off a small cranial ramus, the cranial subsegmental artery, which accompanyies the cranial subsegmental bronchus (Lcr) of the lateral segment; the artery then passes over the dorsal aspect of the cranial subsegmental bronchus (Lcr) and gives off a lateral and a caudal subsegmental artery (Plate XLV). The lateral artery accompanies the lateral subsegmental bronch -us (Ll) lying on its cranial aspect, while the caudal artery passes over the dorsal aspect of the lateral subsegmental bronchus to follow the cranial border of the caudal subsegment -al bronchus (Lca) (Plate XLV) (Sheet 2, figs. 2 - 9). The lateral segmental artery continues as the ventral subsegmental artery; this accompanies the ventral subsegmental bronchus (Lv) lying on its cranial aspect and giving off rami which correspond to the rami arising from the bronchus (Plate XLV) (Sheet 3; Sheet 4, figs. 1 - 4).

The continuation of the lobar artery carries the blood to the medial broncho-pulmonary segment and is known as the medial segmental artery. It lies in close proximity to the medial segmental bronchus on its cranial border (Plate XLV) (Sheet 3). About 7mm from its origin, the medial segmental artery becomes deep in position and lies on the cranial lateral aspect of the segmental bronchus (M), and approximately 11mm from/

from its origin, the medial segmental artery gives off the arteries to the first cranial subsegment. These are,a prominent cranial artery which accompanies the cranial subsegmental bronchus (Mcr1) lying on its cranial medial aspect, and just below it a small artery which accompanies a lateral ramus of the cranial subsegmental bronchus (Sheet 5, figs. 4 - 6; Sheet 6, figs. 1 - 3). At the same level, the segmental artery comes to lie lateral to the segmental bronchus (M) and gives off a ramus to the first lateral bronchus (Mcal1) arising from the caudal subsegmental bronchus (Mca); it runs in a lateral direction lying on the cranial aspect of the bronchus and giving off rami which correspond to the bronchial rami (Plate XLV) (Sheet 5, figs. 5 - 6; Sheet 6, figs. 1 - 2). The segmental artery then gives off the caudal subsegmental artery which accompanies the caudal subsegmental bronchus (Mca) lying on its cranial lateral aspect and gives off several rami which correspond to and accompany the bronchi (Sheet 6; Sheet 7, figs. 4 - 5 & Sheets 7 - 14). 2 - 3mm below the point of origin of the caudal subsegmental bronchus, the segmental artery gives off a lateral subsegmental artery which accompanies the lateral subsegmental bronchus (Ml1) lying on its caudal aspect (Plate XLV) (Sheet 7, figs. 2 - 6), and at the same level, a second cranial subsegmental artery which accompanies the distal cranial subsegmental bronchus (Mcr2) lying on its cranial dorsal aspect (Plate XLV) (Sheet 7, figs. 3 - 6; Sheet 8, figs. 1 - 2).

At this point, the segmental bronchus (M) gives off the middle subsegmental bronchus (Mmid), and the segmental artery lies/

lies between these two bronchi on their lateral aspect (Sheet 7, figs..5 - 6). About 3mm below the level at which the middle subsegmental bronchus arises, the segmental artery gives off an artery which passes over the caudal aspect of the middle subsegmental bronchus and then runs medially to accompany the medial bronchus (Mmidm) given off by the middle subsegmental bronchus (Plate XLV) (Sheet 8, figs. 4 - 6; Sheet 9, figs. 1 - 6). On the level at which the segmental bronchus (M) divides into the medial (Mmed) and lateral (Ml) subsegmental bronchi, the medial segmental artery gives off a middle subsegmental artery and then divides into medial and lateral subsegmental arteries (Sheet 9, figs. 1 - 4). These arteries accompany their respective bronchi and ramify in a similar manner to them, the middle and lateral arteries lying on the lateral aspect of their bronchi, and the medial on the caudal lateral aspect of the bronchi (Plate XLV) (Sheets 9 - 14).

When the cardiac lobar bronchus (C) gives off two lateral bronchi (L1 & L2) to ventilate the area normally ventilated by the lateral segmental bronchus (L), the cardiac lobar artery gives off an artery to accompany each bronchus (Plate XLVI, fig. 1).

<u>The right diaphragmatic lobar artery</u>: as mentioned above, the right pulmonary artery gives off the intermediate lobar artery and the right cardiac lobar artery. Distal to this point, the artery is carrying the blood to the diaphragmatic lobe of the right lung and will be known as the right diaphragmatic lobar artery. It curves round the cranial border of/

of the right cardiac lobar bronchus (C) to reach the lateral aspect of the diaphragmatic lobar bronchus (D) (Plate XLI). The artery then runs in a caudal direction on the dorsal lateral aspect of the lobar bronchus, lying dorsal to the ventral basal (VB) and lateral basal (LB), and lateral to the apical (A) and subapical (SA) segmental bronchi. Generally only one, but in some cases two, large arteries are given off by the lobar artery to a broncho-pulmonary segment. (Plate XLI).

The apical broncho-pulmonary segment, in most lungs, receives only one artery from the lobar artery (Plate XLVII). It accompanies the segmental bronchus (A) lying on its cranial lateral aspect, and it divides into medial, cranial and caudal subsegmental arteries which correspond to and accompany the subsegmental bronchi (Am, Acr & Aca) arising from the segmental bronchus (A) (Plate XLVII & L). The medial subsegmental artery lies on the cranial dorsal aspect of the medial bronchus (Am) and gives off rami which correspond to the bronchial rami (Plate L). The cranial subsegmental artery accompanies the cranial bronchus (Acr) lying on its cranial lateral aspect, and it gives off rami which correspond to the bronchial rami. The caudal subsegmental artery lies on the lateral dorsal aspect of the caudal bronchus (Aca) and gives off arteries which accompany the bronchial rami (Plate XLVII & L).

In a few lungs, two arteries are given off by the lobar artery through this segment; the aproximal artery accompanies the cranial subsegmental bronchus (Acr) and gives off an artery to the medial subsegmental bronchus (Am), while the distal artery/

artery accompanies the caudal subsegmental bronchus (Aca) and its rami (Plate XLI). These arteries are known as the apical segmental arteries of the diaphragmatic lobar artery. Small arteries may be given off by the lobar artery and these accompany the small bronchi of the apical segment which lie in close proximity to the lobar artery.

The ventral basal broncho-pulmonary segment receives an artery from the lobar artery which is known as the ventral basal segmental artery (Plate XLI & XLVII). This artery runs along the cranial lateral aspect of the segmental bronchus (VB) and gives off lateral and medial arteries which correspond to and accompany the dorsal lateral (VBl) and medial (VBm) subsegmental bronchi arising from the segmental bronchus; these arteries usually lie on the cranial aspect of the bronchi (Plate XLVII). The segmental artery then divides into cranial ventral and caudal ventral subsegmental arteries which accompany the cranial ventral (VBcr) and caudal ventral (VBca) subsegmental bronchi of the segmental bronchi; these arteries are usually to be found on the cranial lateral aspect of their corresponding bronchi, and they give off rami which accompany the bronchial collateral rami (Plate XLVII). Very small arteries may be given off by the diaphragmatic lobar artery to that part of the segment which lies in close proximity to the lobar artery, and these arteries accompany the small bronchi in this area.

Usually two arteries are given off by the diaphragmatic lobar artery to the subapical broncho-pulmonary segment (Plate XLI/

XLI, XLVIII & L). These are known as the cranial and caudal subapical segmental arteries. The cranial segmental artery arises from the lobar artery proximal to the caudal artery, and it crosses over the dorsal aspect of the segmental bronchus (SA) to reach the cranial border of the medial subsegmental bronchus (SAm1) (Plate XLVIII & L); it accompanies the bronchus lying on its cranial medial aspect, and it gives off small arteries which correspond to the rami of the bronchus. The caudal segmental artery accompanies the subapical segmental bronchus (SA) lying on its cranial dorsal aspect, it gives off arteries which correspond to the subsegmental bronchi given off by the segmental bronchus (Plate XLVIII). In some lungs, the subapical broncho-pulmonary segment receives only one main artery from the lobar bronchus; in these cases, the artery accompanies the segmental bronchus, while the artery to the medial subsegment arises as the first ramus of the segmental artery. The subapical segment may receive small arteries from the lobar artery and these accompany the small bronchi in the region of the lobar artery.

The usual arrangement of the arteries to this segment supports the findings of Narath (1901) with regard to the arrangement of the pulmonary arteries in the lungs of artiodactyls.

The artery to the medial basal broncho-pulmonary segment is given off by the diaphragmatic lobar artery and, running ventrally over the lateral aspect of the bronchus, it appears on the ventral lateral aspect of the medial basal segmental bronchus/

bronchus (MB). It gives off subsegmental arteries which correspond to and accompany the subsegmental bronchi arising from the segmental bronchus (Plate XLI & L).

The lateral basal broncho-pulmonary segment receives an artery from the diaphragmatic lobar artery which is known as the lateral basal segmental artery (Plate XLI). It lies on the cranial aspect of the segmental bronchus and gives off subsegmental arteries which correspond to and accompany the subsegmental bronchi which arise from the segmental bronchus (LB) (Plate XLVIII).

The medial and dorsal lateral subsegmental arteries accompany the bronchi (LBm1) and (LBl1); they lie on the cranial aspect of the bronchi and give off small arteries which correspond to the rami given off by the bronchi. (Plate XLVIII). An artery is given off which accompanies the subsegmental bronchus (LB2) and then the segmental artery divides into the cranial ventral and caudal ventral subsegmental arteries which lie on the cranial lateral aspect of their respective bronchi and give off smaller arteries which correspond to the rami given off by these bronchi (Plate XLVIII).

After the diaphragmatic lobar artery has given of the above mentioned arteries to the various segments, it carries the blood to the dorsal basal broncho-pulmonary segment and is known as the dorsal basal segmental artery. At first, the artery lies on the dorsal lateral aspect of the bronchus (DB), but it soon moves medially to lie on the dorsal aspect of the bronchus (Plate XLI & XLIX). It gives off subsegmental arteries/

arteries which accompany the dorsal, ventral, medial and lateral subsegmental bronchi arising from the segmental bronch -us (DB). The lateral artery,which accompanies the first lateral subsegmental bronchus (DBl1),lies at first on the cranial aspect and later on the cranial lateral aspect of the bronchus; it gives off small arteries which correspond to the rami of the bronchus (Plate XLIX).

Two subsegmental arteries are usually given off by the segmental artery to the subsegment ventilated by the first dorsal bronchus (DBd1); the cranial or proximal artery accompanies the medial collateral bronchus (DBd1m) arising from the bronchus (DBd1) and lies on its cranial aspect, while the caudal artery accompanies the continuation of the bronchus (DBd1) lying on its cranial dorsal aspect and giving off small arteries which correspond to the bronchial rami (Plate XLIX). A ventral subsegmental artery is given off which accompanies the ventral bronchus (DBv1) and lies on its ventral lateral aspect. (Plate XLIX).

Other arteries are given off to accompany the remaining subsegmental bronchi, and then the segmental artery divides to form small medial and lateral terminal subsegmental arteries which accompany the medial and lateral terminal subsegment -al bronchi respectively and lie on the dorsal lateral aspect of these bronchi (Plate XLIX).

Left Pulmonary Artery.

The left pulmonary artery passes in a caudal and lateral direction from the bifurcation of the pulmonary artery for a short/

short distance before entering the left lung just cranial, lateral and ventral to the main bronchus (Plate XLII). It passes at first in a dorsal direction over the dorsal aspect of the apical-cardiac lobar bronchus and then in a caudal direction on the dorsal lateral aspect of the diaphragmatic lobar bronchus (Plate XLI).

The apical-cardiac lobar arteries: two arteries are given off to this lobe by the left pulmonary artery. Immediately it has entered the lung and before it has passed over the dorsal aspect of the apical-cardiac lobar bronchus, the left pulmonary artery gives off an artery from its dorsal aspect; this artery runs in a dorsal and lateral direction and then cranially to lie on the dorsal medial aspect of the apical segmental bronchus (ACa) of the apical-cardiac lobar bronchus, it is known as the apical segmental artery (Plate XLI & LI). It runs in a cranial direction on the dorsal medial aspect of the segmental bronchus,and after passing the second dorsal subsegmental bronchus the artery generally moves laterally to lie on the dorsal lateral aspect of the segmental bronchus. The segmental artery gives off dorsal and ventral subsegmental arteries which accompany the dorsal, ventral and medial sub-segmental bronchi. The dorsal arteries lie on the cranial medial aspect of the proximal bronchi and on the cranial later-al aspect of the distal bronchi; their position depends on the position of the segmental artery in relation to the seg-mental bronchus, when the segmental artery lies on the dorsal medial aspect of the segmental bronchus the dorsal arteries are/

are cranial medial in position, and when it lies on the dorsal lateral aspect of the segmental bronchus they are cranial lateral in position (Plate LI). The ventral arteries pass over the lateral aspect of the segmental bronchus to lie on the cranial lateral aspect of the ventral bronchus, while the medial arteries lie on the cranial aspect of the medial bronchi (Plate LI). The caudal subsegment of the apical broncho-pulmonary segment, which is ventilated by the subsegmental bronchus (ACl1), receives its blood supply from an artery given off by the artery which supplies the cardiac broncho-pulmonary segment and will be described later (Plate LI). In some lungs, the apical segmental artery gives off near its origin an artery which passes in a dorsal direction and carries the blood to the cranial subsegment of the apical segment of the diaphragmatic lobe.

As the left pulmonary artery passes over the dorsal aspect of the apical-cardiac lobar bronchus (AC), it gives off an artery which carries the blood to the cardiac broncho-pulmonary segment and is known as the cardiac segmental artery (Plate XLI & LI). It runs in a lateral and ventral direction on the lateral aspect of the segmental bronchus (ACc) and gives off cranial and caudal subsegmental arteries which carry the blood to the subsegments ventilated by the cranial lateral (ACcl1), caudal lateral (ACcl2) and the later cranial lateral and caudal lateral bronchi. These arteries lie on the cranial lateral aspect of the bronchi and give off rami which correspond to and accompany the rami given off by the bronchi (Plate LI)/

LI). The first artery given off by the cardiac segmental artery carries the blood to the caudal subsegment of the apical broncho-pulmonary segment which is ventilated by the lateral bronchus (ACal1) (Plate LI). This subsegmental artery runs in a cranial and lateral direction and divides into two rami which accompany the dorsal and ventral rami of the bronch -us; these arteries lie on the medial and lateral aspect of the dorsal and ventral bronchi respectively. This artery provides yet another example to substantiate the findings of Narath (1901) that the branches of a single bronchus may be accompanied by arteries which arise from the pulmonary artery at different points.

The continuation of the cardiac segmental artery supplies the ventral subsegment and lies on the cranial lateral aspect of the ventral subsegmental bronchus (ACcv) (Plate L). The blood therefore is carried to the apical-cardiac lobe of the left lung by two arteries which are given off by the left pulmonary artery, the apical segmental artery and the cardiac segmental artery.

<u>The left diaphragmatic lobar artery</u>: the continuation of the left pulmonary artery after it has given off the apical and cardiac arteries is known as the left diaphragmatic lobar artery because it carries the blood to the diaphragmatic lobe of the left lung. The artery lies on the dorsal lateral aspect of the diaphragmatic lobar bronchus (D) between the dorsal and the ventral lateral bronchi, and running in a caudal direction it gives off rami to each segment of the lobe which/

which are known as segmental arteries (Plate XLI).

The apical segmental artery is the first to be given off by the lobar artery; it arises very near the origin of the latter and runs in a dorsal and caudal direction to reach the medial aspect of the apical segmental bronchus (A) on the level at which it divides into cranial and caudal subsegmental bronchi (Plate LI & LV). The segmental artery then divides into cranial and caudal subsegmental arteries which accompany the cranial and caudal bronchi (Plate LV). The cranial artery usually lies on the medial aspect of the bronchus, and it gives off rami which correspond to the rami arising from the bronchus (Plate LV). The caudal artery lies on the dorsal medial aspect of the caudal bronchus, and it gives off several small arteries which correspond to and accompany the rami given off by the bronchus (Plate LI & LV). In those lungs in which the cranial subsegment of the apical segment of the diaphragmat-ic lobe is large and occupies an extensive area on the dorsal aspect of the apical segment of the apical-cardiac lobe, the cranial subsegmental artery may arise as a branch of the apical segmental artery which supplies the apical segment of the apical-cardiac lobe; in these cases, the artery runs in a dorsal direction to the medial aspect of the cranial subsegment-al bronchus when it bends cranially to accompany the bronchus lying on its medial dorsal aspect (Plate XLII). This shows that the findings of Appleton (1945) with regard to the arrange-ment of the arteries in the human lung also apply in the sheep lung.

The/

The ventral basal segmental artery, which carries the blood to the ventral basal segment, arises from the diaphragmatic lobar artery as the latter passes over the dorsal aspect of the ventral basal segmental bronchus (VB) (Plate LII). The segmental artery runs in a ventral, lateral and caudal direction on the cranial lateral aspect of the segmental bronchus, and it gives off a medial subsegmental artery which runs in a ventral direction passing over the cranial aspect of the segmental bronchus to reach the cranial aspect of the medial subsegmental bronchus (VBm) which it accompanies (Plate LII). A lateral subsegmental artery arises from the segmental artery, and it accompanies the dorsal lateral subsegmental bronchus (VBl) lying on its cranial aspect; it gives off small arteries which correspond to and accompany the rami arising from the subsegmental bronchus (Plate LII).

The segmental artery then gives off a cranial ventral subsegmental artery; this lies on the cranial aspect of the subsegmental bronchus (VBcr) and gives off a number of rami which correspond to and accompany the bronchial rami (Plate LII). The continuation of the segmental artery accompanies the caudal ventral subsegmental bronchus (VBca); it is known as the caudal ventral subsegmental artery, and lying on the cranial aspect of the bronchus it gives off medial and lateral arteries which accompany the medial (VBcam) and lateral (VBcal) bronchi, and a cranial artery which accompanies the cranial bronchus (VBcacr) (Plate LII).

As in the right lung, two arteries are given off by the left/

left diaphragmatic lobar artery to the subapical broncho-pulmonary segment (Plate XLI & LII). The cranial artery is given off by the lobar artery on the level at which the lobar bronchus (D) gives off the subapical segmental bronchus (SA); it runs in a medial, dorsal and slightly caudal direction over the cranial aspect of the segmental bronchus to the cranial dorsal aspect of the medial subsegmental bronchus (SAm1) (Plate LII). The cranial subapical segmental artery, as this artery is termed, follows the bronchus and gives of rami which correspond to and accompany the rami of the bronchi. The caudal artery is given off by the lobar artery at a point approximately 8mm distal to the cranial artery; it runs in a dorsal and slightly caudal and medial direction to reach the cranial lateral aspect of the subapical segmental bronchus (SA), on the level at which the cranial lateral subsegmental bronchus (SAl1) arises (Plate LII). The caudal subapical segmental artery, as this artery is called, accompanies the segmental bronchus, lying on its cranial lateral aspect, and gives off small subsegmental arteries which correspond to the subsegmental bronchi and lie on their cranial dorsal aspect. In addition, small arteries may arise from the lobar artery and accompany small adjacent bronchi. As in the right lung, the arterial supply to this segment endorses the findings of Narath (1901).

The lateral basal segment is supplied by the lateral basal segmental artery which is given off by the lobar artery just cranial to the point at which the segmental bronchus (LB) arises from/

from the lobar bronchus (D) (Plate LIII). This artery runs in a caudal, lateral and ventral direction lying on the cranial lateral aspect of the bronchus (LB); it gives off a medial subsegmental artery which runs in a ventral, lateral and slightly caudal direction, crossing over the cranial aspect of the segmental bronchus (LB), to accompany and lie on the cranial aspect of the medial subsegmental bronchus (LBm1). (Plate LIII). A dorsal lateral subsegmental artery is then given off by the segmental artery; this runs in a caudal, lateral and dorsal direction, and passing over the cranial aspect of the segmental bronchus (LB) it accompanies the dorsal lateral subsegmental bronchus (LBl1). It lies on the cranial dorsal aspect of the bronchus and gives off rami which correspond to the bronchial rami. (Plate LIII).

A cranial ventral subsegmental artery arises from the segmental artery and accompanies the cranial ventral subsegmental bronchus (LBcr); lying on the lateral aspect of the bronchus, it gives off rami which correspond to the bronchial rami (Plate LIII). About the level at which the cranial ventral subsegmental bronchus (LBcr) arises from the segmental bronchus (LB), the segmental artery gives off a lateral subsegmental artery, which accompanies the **subsegmental bronchus** (LBl2), and a medial artery which accompanies the medial bronchus arising from the caudal subsegmental bronchus (LBca) (Plate LIII).

The continuation of the segmental artery accompanies the caudal ventral subsegmental bronchus (LBca) and is known as the/

the caudal ventral subsegmental artery; lying on the cranial lateral aspect of the bronchus, it gives off rami which correspond to and lie on the cranial lateral aspect of the rami arising from the bronchus (Plate LIII). The lateral basal segment also receives a number of small arteries from the lobar artery which accompany small bronchi lying in the region of the lobar artery.

The medial basal segment receives a segmental artery which arises from the lobar artery just cranial to the level at which the medial basal segmental bronchus (MB) arises from the lobar bronchus (D) (Plate LV). The medial basal segmental artery runs in a caudal and ventral direction passing over the lateral aspect of the lobar bronchus to reach the cranial ventral aspect of the segmental bronchus (MB); it then follows the segmental bronchus and gives off subsegmental arteries which accompany the subsegmental bronchi.

The blood to the dorsal basal broncho-pulmonary segment is carried by the dorsal basal segmental artery which is the direct continuation of the lobar artery after it gives off the above mentioned segmentalarteries(Plate XLI & LIV). This artery runs in a caudal direction,lying at first on the dorsal lateral aspect of the dorsal basal segmental bronchus (DB) and later on the dorsal aspect of the bronchus. As in the right lung, the dorsal segmental artery gives off a number of sub-segmental arteries which correspond to and accompany the dorsal, lateral, ventral and medial subsegmental bronchi (Plate LIV & LV). The dorsal subsegmental arteries lie on the/

the dorsal lateral aspect of the bronchi, while the ventral subsegmental arteries lie on the ventral lateral aspect of the bronchi; the arteries accompanying the lateral subsegment -al bronchi lie on the cranial lateral aspect of the bronchi, and the medial subsegmental arteries lie on the cranial dorsal aspect of the bronchi. All these arteries give off rami which correspond to and accompany the bronchi given off by the subsegmental bronchi. The medial and lateral subsegmental arteries which accompany the medial (DBmt) and lateral (DBlt) terminal subsegmental bronchi lie on the dorsal lateral aspect of the bronchi (Plate LIV & LV).

To summarise, following a study of fifteen lungs by means of dissections, corrosion casts and serial sections of the right cardiac lobe of one of these, the pulmonary arteries are described and named with attention to their lobar, broncho-pulmonary segmental and subsegmental distribution.

Generally speaking the arteries may be said to follow the bronchi, with the result that each lobe, broncho-pulmonary segment and subsegment receives it blood supply from an artery which enters the area along with the bronchus.

The pulmonary artery divides into right and left arteries which supply the right and left lungs respectively. The right pulmonary artery gives rise to the right apical lobar artery; this passes to the right apical lobe, and there it divides into cranial and caudal segmental arteries which supply the cranial and caudal segments of the lobe respectively. The right pulmonary artery then enters the right lung ventral to the/

the right main bronchus, and curving round the cranial border of the cardiac lobar bronchus, lies on the lateral aspect of the diaphragmatic lobar bronchus. As it passes round the cardiac lobar bronchus the artery gives off the right intermediate lobar artery to the right intermediate lobe, and then the right cardiac lobar artery to the cardiac lobe. After giving off these branches the right pulmonary artery is known as the right diaphragmatic lobar artery. The right diaphragmatic lobar artery lies on the dorsal lateral aspect of the lobar bronchus and gives off segmental arteries to the ventral basal, lateral basal, apical, subapical and medial basal segments, and is then continued as the dorsal basal segmental artery.

The left pulmonary artery enters the left lung cranial, lateral and ventral to the main bronchus. It immediately gives rise to the apical segmental artery which supplies the apical segment of the apical-cardiac lobe, and then passes over the cranial aspect of the apical-cardiac lobar bronchus to reach the dorsal lateral aspect of the diaphragmatic lobar bronchus. It gives off an artery to the cardiac segment of the apical-cardiac lobe and is then known as the left diaphragmatic lobar artery. The diaphragmatic lobar artery is similar to the artery on the right lung in respect to its course and branches.

It is evident that the arteries do not exactly reproduce the pattern of the bronchial tree at the hilus. The right intermediate and cardiac lobar arteries arise independently from/

from the right pulmonary artery, whereas the lobar bronchi arise from a common opening in the main bronchus. The apical-cardiac lobe of the left lung is supplied by two segmental arteries which arise independently from the left pulmonary artery. These examples show that the findings of Narath (1901) and Appleton (1944) with regard to the hilar arrangement of the pulmonary arteries in the artiodactyl and human lung respectively apply in the sheep.

Usually each broncho-pulmonary segment is supplied by one main artery, but there are exceptions, for example:

(1) the subapical segments of the right and left diaphragmatic lobes are supplied by two arteries.

(2) The caudal subsegment of the apical segment of the apical-cardiac lobe receives its blood supply from an artery given off by the cardiac segmental artery.

(3) In some lungs, an area of the subapical subsegment of the caudal segment of the right apical lobe receives its blood supply from an artery given off by the cranial segmental artery.

(4) In some lungs, the cranial subsegment of the apical segment of the left diaphragmatic lobe receives its blood supply from an artery given off by the apical segmental artery to the apical-cardiac lobe.

(5) Many segments receive small arteries which arise from a lobar artery and accompany the small bronchi in the region of the lobar artery.

These examples indicate that the findings of Narath (1901) with/

with regard to the pulmonary arteries in the lungs of artiodactyls, and of Appleton (1945) and Melnikoff (1924) with regard to the pulmonary arteries in the human lung apply to these arteries in the sheep.

As a general rule the arteries are to be found on the cranial aspect of bronchi which run transversely or oblique to the longitudinal axis of the lungs, on the lateral aspect of bronchi which run in a caudal direction parallel to the longitudinal axis of the lungs, and on the medial aspect of bronchi which run in a cranial direction parallel to the longitudinal axis of the lungs.

Description of the Pulmonary Veins.

The pulmonary veins carry all the blood which passes from the lungs to the left atrium of the heart. It will be recalled that the blood is carried to the lungs by both the pulmonary artery and the bronchial artery.

A number of radicles become confluent to form the pulmonary veins; Miller (1947) states that "the pulmonary veins can be traced to four sources of origin. (1) The capillary network within the pleura which is derived in man and animals with a thick pleura, from subdivisions of the bronchial artery; in animals with a thin pleura, from subdivisions of the pulmonary artery. (2) The capillary network in the ductuli alveolares which gives origin to two venous radicles, one on either side of a ductulus. As will be noted later, these two radicles are the only veins found within the primary lobule and carry away blood from the ductulus and adjoining atria.

(3)/

(3) The two venous radicles, one on either side, which leave the bronchi at the place where bronchi or bronchioli divide. (4) The network of capillaries derived from the pulmonary artery situated within the walls of the sacculi alveolares".

The pulmonary veins have a peripheral position in the primary lobule, and this peripheral position is maintained by the larger veins which drain the broncho-pulmonary subsegments and segments of a lobe; they are found in the connective tissue planes between these subsegments or segments.

Unlike the pulmonary arteries the pulmonary veins are not closely related to the bronchi, in fact, lying as they are in the intersegmental connective tissue planes, they are to be found as far away as possible from the bronchi in the middle of the space between the bronchi. The systemic veins tend to duplicate the course of the systemic arteries, but the pulmonary veins follow a different course and generally lie on the opposite side of the bronchi to the pulmonary arteries. The pulmonary artery is usually to be found lying cranial and lateral to the bronchus, while the pulmonary vein is usually to be found lying caudal and medial to the bronchus.

From the point of view of topography, the larger veins may be grouped into two categories, the superficial and the deep veins. The superficial veins lie just below the pleura and drain the superficial parts of the segment; the deep veins lie in the connective tissue planes between the segments which they drain. It is possible for a superficial vein to become a deep vein due to the absence of a fissure, when it will drain/

drain part of the adjacent segment in addition to the segment which it normally drains.

The pulmonary veins are thicker, tougher and more elastic than most systemic veins, in order to withstand expansions and contractions of the lungs, and unlike the systemic veins there are no anastomoses between the pulmonary veins except near the periphery of the lung. Here anastomoses do occur between the smaller branches, with the result that there is a link between the neighbouring lobules although their arterial blood supply is usually independent (Schäfer and Symington (1896) .

The pulmonary veins unlike some of the systemic veins have no valves; these are rendered unnecessary because the mean pressure of the blood in the pulmonary veins is very low, being at or near zero, and somewhat greater than that in the left auricle (Evans, 1952). Indeed, Evans states that "Experiments on the heart-lung preparation showed that a rise in the aortic pressure, while the inflow into the heart from the venous reservoir was kept constant, was accompanied by a rise in the pulmonary artery pressure. This was at first ascribed to "back pressure", i.e. to a relative failure of the left auricle to deal with the blood flowing into it. This cannot be the case, however, for the mean left auricular pressure is not raised ".

The pulmonary veins from the right and left lungs carry the blood to the left atrium of the heart. The left atrium forms the posterior part of the base of the heart, lying behind/

behind the pulmonary artery and the aorta and above the left ventricle. The auricle of the left atrium extends outward and forward on the left side of the heart to terminate just behind the pulmonary artery. The pulmonary veins open into the medial and caudal walls of the atrium. Two openings can be seen in the caudal part of the medial wall, and these are the openings of the veins from the apical and cardiac lobes of the right lung. In the caudal wall of the atrium there are the two large openings into which the veins draining the diaphragmatic lobes of the right and left lungs open. A smaller opening for the apical-cardiac lobar vein from the left lung is present just cranial and to the left of the caudal openings. The interior of the atrium is smooth with the exception of the auricle which is made rough by the 'musculi pectinati'.

The veins have been studied in thirteen lungs by means of dissections, corrosion casts and serial sections of the right cardiac lobe of one of these. In this description, the intention is to make mention only of the larger veins draining the various lobes, bronchi-pulmonary segments and subsegments to avoid the description becoming too involved and cumbersome. However, a more detailed description of the veins draining the cardiac lobe is attempted, as an example of the position of the smaller veins in relation to the bronchi and arteries.

Right Lung.

The right apical lobar vein: this vein drains the apical lobe of the right lung and opens into the left atrium of the heart on its medial wall as described above. It is very short/

short and is formed by a number of tributaries which drain the cranial and caudal broncho-pulmonary segments of the lobe (Plate LVI).

The cranial segmental vein is formed by the veins which drain the ventral and cranial lateral subsegments on the level at which the cranial segmental bronchus (Cr) gives off the cranial lateral subsegmental bronchus (Crl) (Plate LVIII). Lying caudal and medial to the cranial segmental bronchus (Cr) in a subpleural position, the vein runs in a dorsal, caudal and medial direction following the caudal medial border of the bronchus. It is joined by the vein draining the apical subsegment, which passes over the medial aspect of the segmental bronchus (Cr) approximately on the level at which it gives off the apical subsegmental bronchus (Cra) (Plate LVIII). The cranial segmental vein now passes in a caudal, medial and almost horizontal direction towards the heart; it is joined by a number of veins which drain the caudal segment and together they form the apical lobar vein (Plate LVI & LVIII). The latter is very short and passes medially, ventral to the trachea, to enter the left atrium of the heart along with the cardiac lobar vein (Plate LVI). During its course the cranial segmental vein lies ventral to the right apical lobar artery and the lobar vein lies ventral to the right pulmonary artery.

The cranial broncho-pulmonary segmental bronchus (Cr) gives off three subsegmental bronchi, namely the apical (Cra), cranial lateral (Crl) and ventral (Crv), which ventilate the apical, cranial lateral and ventral subsegments. These subsegments/

subsegments are supplied with blood by the subsegmental arteries, which are branches of the cranial segmental artery given off by the right apical lobar artery, and by branches of the bronchial arteries; we have seen in the description of the pulmonary arteries that these segments are generally quite independent as regards their blood supply. In this description of the venous drainage, we shall see that a vein which drains an area with an independent arterial supply may also drain the adjacent part of a neighbouring area.

The ventral subsegment of the right apical lobe is drained mainly by the ventral subsegmental vein which is formed by a number of tributaries; these drain the areas of the subsegment which are ventilated by rami given off by the ventral subsegmental bronchus (Crv). The dorsal and ventral areas at the apex of the ventral subsegment, which are ventilated by the terminal bronchi (Crvd) and (Crvv) of the ventral subsegmental bronchus, are drained mainly by two veins, a dorsal and a ventral. The dorsal vein lies caudal and ventral to the bronchus (Crvd) in the connective tissue plane between the dorsal and ventral areas, and it is formed by a number of tributaries; each tributary drains an area of lung tissue, which is ventilated by a ramus of the dorsal terminal bronchus, and also the adjacent part of the area which adjoins the connective tissue plane in which it lies (Plate LVIII). The ventral vein lies caudal and ventral to the ventral terminal bronchus (Crvv) and is formed in the same way by a number of tributaries; it lies in the plane between the ventral area and/

and the cranial lateral subsegment (Plate LVIII). The dorsal and ventral veins are both classed as deep veins; they conjoin to form the ventral subsegmental vein on the caudal ventral aspect of the ventral subsegmental bronchus, about the level at which it divides into dorsal and ventral terminal bronchi (Plate LVII). Running in a caudal and dorsal direction, the ventral subsegmental vein now becomes subpleural in position and may be classed as a superficial vein; it follows the caudal ventral and medial border of the subsegmental bronchus (Crv), and on the level at which the bronchus gives off the first lateral bronchus (Crvl), it receives a tributary which drains the area ventilated by the lateral bronchus (Crvl) and is formed by lesser tributaries in the same way as the previous veins (Plate LVIII).

Medial to the point at which the cranial segmental bronchus gives off the cranial lateral subsegmental bronchus (Crl), the ventral subsegmental vein is joined by the vein which drains the cranial lateral subsegment and is known as the cranial lateral subsegmental vein (Plate LVIII). This vein is formed by a number of tributaries which drain the subsegment; it is subpleural in position and lies on the caudal medial aspect of the subsegmental bronchus. Passing in a dorsal direction it joins the ventral subsegmental vein just after the latter has passed over the medial aspect of the cranial lateral subsegmental bronchus (Plate LVIII). The cranial segmental vein is now formed and its course is described above.

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The apical subsegmental vein, which drains the apical subsegment, is formed by a number of tributaries which drain the various parts of the subsegment and the adjacent parts of the area ventilated by the first lateral collateral bronchus (Crvl) of the ventral subsegmental bronchus (Crv). This vein runs in a caudal direction, and at first, it lies on the later -al ventral aspect of the subsegmental bronchus, but later, it lies on the medial aspect of the bronchus, and finally, as it passes over the medial aspect of the cranial segmental bronchus to join the cranial segmental vein, it becomes subpleural in position (Plate LVI & LVIII).

The caudal broncho-pulmonary segment of the right apical lobe is drained by a number of veins which open into the cranial segmental vein. The vein, which drains the caudal lateral subsegment and may be called the caudal lateral subsegmental vein, enters the cranial segmental vein at the point at which the latter becomes the right apical lobar vein (Plate LVI & LVIII). This subsegmental vein is formed by a number of tributaries, each of which lies in the connective tissue plane between the areas which it drains, and it runs in a dorsal and medial direction on the cranial medial aspect of the caudal lateral subsegmental bronchus (Cal) (Plate LVIII). It becomes superficial a short distance before it joins the cranial segmental vein.

The subapical subsegment is drained by veins which open into the dorsal aspect of the cranial segmental vein; there are usually two, but sometimes there may be three, veins draining/

draining the subapical subsegment, and they are formed by a number of tributaries which drain areas of the subapical subsegment. These tributaries become confluent to form a cranial and a caudal vein, or a cranial, a middle and a caudal vein, depending on the number present, which arise from the corresponding parts of the subsegment and run in a ventral and medial direction to become superficial just before they open into the cranial segmental vein (Plate LVI & LVII). Quite frequently, a small vein,which arises in the connective tissue plane between the apical and subapical subsegment,passes in a ventral, medial, and caudal direction to enter the cranial segmental vein distal to the above vein (Plate LVIII); if this small vein is absent, the area is drained by a tributary of one of the veins draining the subapical subsegment.

<u>The right cardiac lobar vein</u>: the right cardiac lobe is drained by the right cardiac lobar vein. This is formed by the union of the vein which drains a large part of the lateral segment and is known as the lateral segmental vein, and the vein which drains the remainder of the lobe and is known as the medial segmental vein. These two veins join approximately 3mm below the level at which the lobar bronchus gives off the lateral segmental bronchus (L) (Plate XLV) (Sheet 2, figs. 8 - 9). The lobar vein lies at the cranial medial border of the lobe, in a subpleural position on the cranial aspect of the right cardiac lobar artery, and runs in a dorsal and medial direction. It enters the left atrium alongside, but caudal and ventral to the right apical lobar vein; shortly before/

before it enters the atrium, the vein generally receives a small tributary which lies in the intersegmental connective tissue plane between the subapical subsegment of the right apical lobe and the apical segment of the diaphragmatic lobe. This small vein receives blood from both the above segments and passes in a ventral direction in the connective tissue plane between them to join the lobar vein (Plate LVI & LVII).

The lateral segmental vein drains most of the lateral broncho-pulmonary segment and, as will be seen, part of the caudal subsegment of the medial broncho-pulmonary segment (Plate XLV). The vein is formed by a number of tributaries which drain the areas ventilated by the first lateral ramus (Mcal1) of the caudal subsegmental bronchus (Mca) and the second lateral ramus of the caudal subsegmental bronchus (Sheet 6, fig. 5); it lies at first in the connective tissue plane between these areas and then passes in a dorsal and medial direction between the cranial and caudal rami of the lateral bronchus (Mcal1) (Plate XLV) (Sheet 4, fig. 6; Sheet 5, figs. 1 - 3). Still passing in a dorsal and medial direction, the vein now lies caudal and medial to the ventral subsegmental bronchus (Lv) of the lateral segment in the intersegmental plane between the lateral and medial segments (Plate XLV) (Sheet 4, figs. 5 - 6); it receives tributaries which lie in the connective tissue planes between the areas ventilated by the rami of the ventral subsegmental bronchus, and gradually it comes to lie medial to the ventral subsegmental bronchus (Lv) (Sheet 4, figs. 1 - 4). A small tributary, which arises from/

from the wall of the segmental bronchus (M) on the level at which the caudal subsegmental bronchus (Mca) is given off, runs in a cranial and dorsal direction to join the segmental vein (Plate XLV) (Sheet 4, figs. 1 - 6; Sheet 5, figs. 1 - 3). About 2mm below the level at which the lateral subsegmental bronchus (Ll) arises from the lateral segmental bronchus (L), the segmental vein receives a lateral vein which drains the lateral and caudal subsegments (Plate XLV) (Sheet 3, fig. 2). This vein lies in the plane between the lateral, ventral and caudal subsegments, and runs in a ventral and medial direction to join the lateral segmental vein. It is formed by two main tributaries, a lateral and a caudal; the caudal tributary lies just dorsal to the caudal subsegmental bronchus (Lca), and the lateral tributary lies onthe caudal ventral aspect of the lateral subsegmental bronchus (Ll) (Plate XLV) (Sheet 2, figs. 4 - 9). A small vein which drains the dorsal sub-segment also enters the segmental vein at this level. (Sheet 1, figs. 6 - 9; Sheet 2; Sheet 3, figs. 1 - 2). The lateral segmental vein then runs in a cranial and medial direction over the lateral aspect of the medial segmental artery to join the medial segmental vein and so form the right cardiac lobar vein (Plate XLV).

The medial segmental vein is formed in the ventral part of the cardiac lobe by the union of the veins which drain the medial and lateral subsegments of the medial segment. The lateral subsegmental vein, which is formed by tributaries draining the ventral parts of the medial and lateral subsegments, lies/

lies in the connective tissue plane between the lateral and medial subsegments, cranial to the subsegmental bronchi (Ml) and (Mmed); it passes in a dorsal direction, still in the connective tissue plane, and gradually comes to lie between the lateral (Ml) and medial (Mmed) subsegmental bronchi (Sheet 11 - 14). At this level it is joined by a vein which lies in the connective tissue plane between the lateral and middle subsegments and is formed by tributaries which drain the ventral areas of these subsegments adjacent to the plane in which it lies (Sheet 11, figs. 3 - 5). The subsegmental vein continues to run in a dorsal direction receiving tributaries which drain the lateral subsegment and the adjacent areas of the medial and middle subsegments; as it approaches the level at which the medial (Mmed) and lateral (Ml) subsegmental bronchi join to form the medial segmental bronchus (M), the vein comes to lie on the cranial aspect of the lateral subsegmental bronchus (Ml) (Sheet 10, figs. 1 - 4); it is still receiving tributaries from the lateral, medial and middle subsegments. On the level at which the lateral and medial subsegmental bronchi join, the lateral subsegmental vein receives the vein which drains the medial subsegment (Plate XLV). This vein is formed by a number of tributaries, and it originally lies in the plane between the areas ventilated by the medial subsegmental bronchus (Mmed) and the first medial ramus of the medial subsegmental bronchus (Sheet 11 - 12). As this medial bronchial ramus joins the medial subsegmental bronchus, the vein comes to lie on the cranial aspect of the subsegmental bronchus (Mmed) and continues

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to receive tributaries which drain the subsegment (Sheet 9, figs. 3 - 6; Sheet 10, figs. 1 - 3).

The segmental vein is now formed and lies on the cranial lateral aspect of the segmental bronchus (M); it shortly afterwards receives another vein on its lateral aspect (Sheet 8, fig. 1). This latter vein originates in the ventral part of the lobe, in the connective tissue plane between the middle and caudal subsegments on the cranial aspect of the caudal subsegmental bronchus (Mca); it receives tributaries which drain the adjacent parts of the subsegments and runs in a dorsal and slightly cranial direction (Plate XLV) (Sheet 12, figs. 1 - 2). It becomes deeper in position as the middle subsegment becomes more medially situated and receives tributaries which drain the cranial part of the lateral subsegment, the lateral part of the middle subsegment and the caudal subsegment (Sheet 10). Shortly before it enters the medial segmental vein, the vein lies, at first, in the plane between the lateral and caudal subsegments, and then in the plane between the caudal subsegment and the medial segment just lateral to the medial segmental artery (Sheet 8; Sheet 9, figs. 1 - 2). The segmental vein continues in a dorsal direction on the cranial lateral aspect of the segmental bronchus (M) (Plate XLV); it receives a small vein which drains the proximal part of the middle subsegment and passes in a cranial direction between the medial segmental bronchus, the middle subsegmental bronchus and the medial segmental artery (Sheet 7, figs. 5 - 6). The segmental vein soon becomes/

becomes situated a few millimetres from the segmental bronchus, although still lying on its cranial lateral aspect, and receives tributaries which drain the cranial and lateral subsegments. A short distance below the level at which the caudal subsegmental bronchus (Mca) arises from the medial segmental bronchus, the segmental vein receives a tributary which drains the caudal subsegment (Plate XLV); this originates in the caudal lateral border of the subsegment in the connective tissue plane between the areas ventilated by the second and third lateral rami of the caudal subsegmental bronchus (Mca) (Sheet 9, figs. 3 - 4). Passing in a cranial direction, it soon receives several more tributaries which drain the caudal subsegment, and comes to lie in the plane between the caudal subsegment and the medial segment where it also receives tributaries from the adjacent part of the medial segment (Sheet 6, fig. 5). The vein now runs in a dorsal and medial direction to enter the segmental vein, and at the same time it receives a tributary which lies in the plane between the ventral part of the ventral subsegment of the lateral segment and the medial segment (Sheet 5, fig. 4). The segmental vein continues to run in a dorsal direction to join the lateral segmental vein and form the cardiac lobar vein.

From this detailed study it is evident that the deep veins lie in the connective tissue planes which exist between the various areas of lung tissue, and the superficial veins, for example the lobar vein, lie in a subpleural position.

<u>The right intermediate lobar vein</u>: the intermediate lobe of/

of the right lung is drained by this vein (Plate LVI & LVII). It is formed by the veins which drain the dorsal and ventral segments. The vein draining the ventral segment lies on the caudal medial aspect of the ventral segmental bronchus (Iv) and is formed by a number of tributaries which drain the various subsegments of the ventral segment (Plate LVI). Running in a cranial, dorsal and medial direction in the plane between the dorsal and ventral segments, it is joined by the vein draining the dorsal segment. The latter lies on the medial aspect of the dorsal segmental bronchus (Id) and passing in a cranial direction drains the segment (Plate LXII). The lobar vein runs in a cranial, medial and dorsal direction, lying on the caudal medial aspect of the lobar bronchus (I), to enter the right diaphragmatic lobar vein on its ventral aspect just before the latter enters the left atrium.

The right diaphragmatic lobar vein: the right diaphragmatic lobe is drained by this vein. It is formed as a continuation of the vein which drains the dorsal basal segment of the lobe, and it runs in a cranial direction on the medial ventral aspect of the lobar bronchus (D), receiving tributaries which drain the other segments of the lobe; near its termination, it becomes subpleural in position, and passing medial and dorsal to the right intermediate lobe, it bends medially and ventrally to enter the caudal part of the left atrium alongside the left diaphragmatic lobar vein. The right diaphragmatic lobar vein receives the right intermediate lobar vein, which drains the right intermediate lobe, on its ventral/

ventral aspect just before it enters the atrium. Except in its terminal part, the last 2mm, the lobar vein may be classed as a deep vein, being completely surrounded by lung tissue (Plate LVI, LVII & LXII). The segmental veins which open into the lobar vein will be described separately.

The arrangement of the veins draining the apical broncho-pulmonary segment of the right diaphragmatic lobe appears to depend on the level at which the segmental bronchus (A) arises from the lobar bronchus (D). In the majority of lungs examined, the bronchus (A) arises cranial to, or on a level with, the ventral basal segmental bronchus (VB); however, in a few lungs, it arises caudal to the ventral basal segmental bronchus.

When the segmental bronchus (A) arises cranial to,or on a level with, the ventral basal segmental bronchus (VB), the segment is drained mainly by a vein which will be called the apical segmental vein. Two veins, a cranial and a caudal, which drain the medial, cranial and caudal subsegments of the apical segment, form the segmental vein on the caudal medial aspect of the segmental bronchus (A) on the level at which it gives off the medial subsegmental bronchus (Am) (Plate LXII). The segmental vein then runs, in a ventral and medial direction, in the connective tissue plane between the apical and subapical segments, and passing over the medial aspect of the diaphragmatic lobar bronchus (D) it enters the dorsal aspect of the right diaphragmatic lobar vein (Plate LXII). The caudal vein is formed by a lateral and a medial tributary.

The/

The medial tributary lies in the plane between the medial and caudal subsegments; it drains the medial subsegment and the medial part of the caudal subsegment as well as the adjacent part of the subapical segment (Plate LXII). The lateral tributary drains the dorsal part of the caudal subsegment and the adjacent part of the subapical segment; it passes in a medial direction, caudal to the caudal subsegmental bronchus (Aca), to join the medial tributary and form the caudal vein (Plate LXII). The cranial vein drains the cranial subsegment for the most part, but receives tributaries which lie in the planes between the cranial and caudal subsegments and between the cranial and medial subsegments, and drain the adjacent parts of these subsegments. The cranial vein lies on the caudal aspect of the cranial subsegmental bronchus (Acr), in the plane between the cranial and caudal subsegments, and passes in a caudal and ventral direction to join the caudal vein (Plate LIX & LXII).

When the apical segmental bronchus arises from the lobar bronchus caudal to the ventral basal segmental bronchus, it is usual to find an additional vein entering the apical segmental vein near its termination. This tributary is formed in the connective tissue plane between the subapical subsegment of the right apical lobe and the apical segment of the diaphragmatic lobe; it drains adjacent parts of both segments and then passes in a caudal, ventral and medial direction over the medial aspect of the right main bronchus, just caudal to the bifurcation of the trachea, to enter the segmental vein. This/

This vein replaces the small vein which usually drains this area and enters the right cardiac lobar vein.

In some lungs, a vein is found in the connective tissue plane between the apical and subapical segments; it is formed by tributaries which drain the areas of these segments adjacent to the connective tissue plane,and it runs in a ventral and medial direction to enter the dorsal aspect of the diaphragmatic lobar vein, a short distance distal to the point at which the apical segmental vein opens (Plate LXII).

The ventral basal broncho-pulmonary segment of the right diaphragmatic lobe is drained mainly by the ventral basal segmental vein (Plate LVI & LVII). This vein is formed by the union of the veins draining the cranial ventral and caudal ventral subsegments, on the level at which the segmental bronchus (VB) divides into the cranial ventral (VBcr) and caudal ventral (VB ca) subsegmental bronchi; it lies caudal and medial to the bronchus, and from its point of origin, runs in a dorsal and medial direction in the connective tissue plane between the ventral basal and lateral basal segments (Plate LVI & LIX). The vein passes over the ventral aspect of the diaphragmatic lobar bronchus, when it lies in the plane between the ventral basal segment and the intermediate lobe of the right lung, and it then passes dorsal to the dorsal segmental bronchus (Id) of the intermediate lobe to enter the ventral lateral aspect of the lobar vein, just distal to the point at which the apical segmental vein joins the lobar vein (Plate LVI). As mentioned above, the segmental vein/

vein is formed by the veins draining the cranial ventral and caudal ventral subsegments.

The cranial vein is formed in the usual way by a number of tributaries which drain the various areas of the cranial ventral subsegment and the adjacent areas of the caudal ventral subsegment. It lies on the caudal medial aspect of the subsegmental bronchus (VBcr) in the plane between the cranial ventral and caudal ventral subsegments and runs in a cranial, dorsal and medial direction to meet the caudal vein (Plate LIX). The caudal vein is formed by tributaries which drain the caudal ventral subsegment and the adjacent part of the lateral basal segment; it lies on the caudal medial aspect of the caudal ventral subsegmental bronchus (VBca), in the plane between the ventral basal and lateral basal subsegments, and passes in a cranial, dorsal and medial direction to meet the cranial vein and form the segmental vein (Plate LVI, LVII & LIX).

The segmental vein receives a lateral and a medial vein. The lateral vein is formed by tributaries which drain the dorsal lateral subsegment and the adjacent parts of the ventral basal and lateral basal segments; lying in the plane between the ventral basal and lateral basal segments caudal to the dorsal lateral subsegmental bronchus (VBl), it runs in a ventral and medial direction to join the segmental vein close to the level at which the segmental bronchus (VB) gives off the dorsal lateral subsegmental bronchus (VBl) (Plate LIX). The medial vein, which is formed by tributaries draining the medial/

medial subsegment, lies medial to the subsegmental bronchus (VBm) and runs in a dorsal and medial direction to join the segmental vein (Plate LVI & LIX).

There are two more small medial veins which usually open into the segmental vein; one lies in the connective tissue plane between the ventral basal segment and the intermediate lobe, and receives tributaries which drain the adjacent areas of the lung tissue; the other vein lies in the plane between the ventral basal and lateral basal segments, and runs in a dorsal and medial direction, receiving tributaries from the above segments, to enter the ventral basal segmental vein (Plate LVI). The veins draining the ventral basal segment are deep veins and do not appear in a subpleural position.

The subapical segment is drained for the most part by the subapical segmental vein, which lies caudal and medial to the segmental bronchus (SA) in the connective tissue plane between the subapical and dorsal basal segments of the diaphragmatic lobe (Plate LXII). This vein runs in a cranial, ventral and slightly medial direction, and passes over the medial aspect of the lobar bronchus to join the lobar vein, just caudal to the level at which the lobar bronchus gives off the subapical segmental bronchus (Plate LXII). The subapical segmental vein is formed by a medial and a lateral vein, which drain the caudal dorsal subsegment of the subapical segment and the adjacent part of the dorsal basal segment; as it passes towards the lobar vein, the segmental vein receives a number/

number of dorsal, medial and lateral tributaries which lie in the planes between the dorsal, medial and lateral subsegments draining these subsegments and the adjacent parts of the dorsal basal segment (Plate LX & LXII). Throughout its course the subapical segmental vein lies deep in position.

The lateral basal segment of the right diaphragmatic lobe is drained mainly by the lateral basal segmental vein. This vein is formed caudal and medial to the segmental bronch-us (LB), on the level at which it divides into the cranial ventral (LBcr) and caudal ventral (LBca) subsegmental bronchi, by the union of the veins draining the cranial ventral and caudal ventral subsegments (Plate LX). These veins lie caudal and medial to their respective bronchi; the cranial vein receives tributaries which drain the cranial ventral subsegment and the adjacent part of the caudal ventral subsegment, and lying in the plane between the cranial ventral and caudal ventral subsegments, it runs in a cranial, dorsal and medial direction to reach the caudal medial aspect of the segmental bronchus (LB). The caudal vein lies in the plane between the caudal ventral subsegment and the first lateral subsegment of the dorsal basal segment, and it receives tributaries which drain the adjacent areas of lung tissue; running in a cranial, dorsal and medial direction, it joins the cranial vein and forms the segmental vein (Plate LX).

The segmental vein lies in the plane between the lateral basal and dorsal basal segments on the caudal medial aspect of the segmental bronchus (LB); it runs in a cranial, dorsal and medial/

medial direction receiving several tributaries before it passes ventral to the lobar bronchus in the plane between the lateral basal, medial basal and dorsal basal segments to enter the lateral aspect of the diaphragmatic lobar vein (Plate LVI). The segmental vein receives the veins which drain the dorsal lateral and medial subsegments; these lateral and medial veins lie caudal to their respective bronchi in the connective tissue plane between the subsegments, and the lateral basal and dorsal basal segments; they drain their subsegments and the adjacent parts of the lateral basal and dorsal basal segments (Plate LVII & LX). The segmental vein draining the lateral basal segment may be classed as a deep vein.

The medial basal segment is drained by two main veins, a small cranial vein and a larger caudal vein. The cranial vein lies in the plane between the ventral subsegment and the rest of the medial basal segment, and receives tributaries which drain the subsegment and the adjacent parts of the segment; it then runs in a cranial, dorsal and medial direct -ion to enter the ventral aspect of the lobar vein (Plate LXII). The larger caudal vein lies caudal and dorsal to the segmental bronchus (MB) in the plane between the medial basal and dorsal basal segments; it receives tributaries, which drain the dorsal and caudal subsegments of the medial basal segment and the cranial part of the ventral subsegment of the dorsal basal segment, and lying in the plane between the medial basal and dorsal basal segments, it runs in a cranial, dorsal/

dorsal, and slightly medial direction to enter the lobar vein. The veins draining the medial basal segment all lie deep in position. (Plate LVII & LXII).

The dorsal basal segment is drained, for the most part, by the dorsal basal segmental vein which lies on the ventral medial aspect of the segmental bronchus. Running in a cranial direction it is joined by either the lateral basal, the subapical, or the caudal medial basal segmental vein to form the diaphragmatic lobar vein (Plate LVI & LXII). The segmental vein is formed by the union of a medial and a lateral vein which drain the medial and lateral terminal subsegments of the segment. Lying medial and ventral to their respective bronchi, the veins unite just distal, ventral and medial to the point at which the segmental bronchus (DB) divides into the medial (DBmt) and lateral (DBlt) terminal bronchi (Plate LVI). The segmental vein runs in a cranial direction, lying medial and ventral to the segmental bronchus (DB), in the connective tissue plane between the ventral, and dorsal or medial subsegments of the dorsal basal segment. The segmental vein is joined by small lateral, dorsal, medial & ventral veins which drain the small lateral, dorsal, medial and ventral subsegments, and larger veins which drain the larger lateral, dorsal, medial and ventral subsegments.

The lateral vein lies caudal and medial to the subsegment -al bronchus (DBl1) in the connective tissue plane between the first lateral and the adjacent lateral subsegments, and it runs in a cranial, medial and dorsal direction, passing ventral to/

to the segmental bronchus (DB), to join the segmental vein (Plate LXI); it is formed by a number of small tributaries which drain the lateral subsegment and the adjacent part of the dorsal subsegment. The dorsal vein lies caudal to the subsegmental bronchus (DBd1), in the plane between the dorsal subsegment and the immediately adjacent caudal part of the dorsal basal segment, and receives tributaries from the dorsal subsegment and the adjacent part of the dorsal basal segment; it runs in a ventral and cranial direction to enter the segmental vein. The ventral vein lies caudal to the subsegmental bronchus (DBv1), in the plane between the ventral subsegment and the immediately adjacent caudal part of the dorsal basal segment, and runs in a cranial and dorsal direct -ion to enter the segmental vein. In those lungs in which the medial subsegmental bronchus (DBm1) is present, the medial subsegment is drained by a vein which lies caudal and medial to the subsegmental bronchus, in the plane between the medial subsegment and the immediately adjacent part of the dorsal basal segment, and passes in a cranial and lateral direction to join the segmental vein.(Plate LVI, LXI &LXII).

Left Lung.

The apical-cardiac lobar vein: the apical-cardiac lobe is drained by this vein which is very short, 1cm in length, being formed by the union of the vein which drains the apical broncho-pulmonary segment with the vein which drains the cardiac broncho-pulmonary segment. The lobar vein passes medially to enter the left atrium just cranial and to the left of the

caudal/

caudal openings for the left and right diaphragmatic lobar veins. (Plate LVI).

The apical segmental vein, which drains the greater part of the apical broncho-pulmonary segment, lies ventral and slightly medial to the segmental bronchus (ACa) in a subpleural position; it is formed by small tributaries which drain the terminal subsegments and lie in the usual way in the connective tissue planes between the subsegments (Plate LVI & LXIII). It passes in a caudal and ventral direction and receives several more tributaries which drain the dorsal and ventral subsegments; these veins, which drain the subsegments, lie caudal and medial to their respective bronchi and run in a caudal and dorsal, or caudal and ventral, direct-ion, as the case may be, towards the segmental vein passing medial to the segmental bronchus (ACa) (Plate LVI, LVII & LXIII).

Near its termination, the segmental vein bends medially and joins the cardiac segmental vein (Plate LVI); shortly before it does so, it receives three larger veins:-

(1). This vein, draining the ventral subsegment ventilated by the bronchus (ACav1), lies medial and caudal to the subsegmental bronchus (ACav1) in the connective tissue plane between the ventral subsegment and the cardiac segment. It is formed by several tributaries and runs in a caudal, dorsal and medial direction; just before it enters the segmental vein, it becomes subpleural in position and passes ventral to the segmental bronchus (ACa) (Plate LXIII).

(2)/

(2). This vein, which drains the caudal dorsal subsegment ventilated by the bronchus (ACad1), lies lateral to the bronchus (ACad1); it is formed by a number of small tributaries and runs in a ventral and slightly caudal direction to lie cranial to the bronchus; after passing ventral to the apical-cardiac lobar artery, and dorsal to the segmental bronchus (AC), it enters the segmental vein. In its terminal part, this vein lies innthe plane between the ventral and caudal dorsal subsegments (Plate LXIII).

(3). This vein, draining the caudal subsegment of the apical segment, lies on the lateral aspect of the subsegmental bronchus (ACal1). It is formed by a dorsal and a ventral vein which drain the areas ventilated by the dorsal and ventral rami of the bronchus (ACal1), and then it runs in a cranial and medial direction in the connective tissue plane between the ventral and caudal subsegments; passing ventral to the segmental bronchus (ACa), where it is subpleural in position, it enters the segmental vein shortly before the latter joins the cardiac segmental vein (Plate LXIII).

Frequently, a dorsal vein, which lies in the connective tissue plane between the caudal dorsal subsegment of the apical segment and the apical segment of the diaphragmatic lobe and drains the adjacent parts of these areas, runs in a ventral direction, passing lateral to the left diaphragmatic lobar artery and medial to the segmental bronchus (ACa), to enter the segmental vein.

The cardiac segmental vein, which drains most of the cardiac/

cardiac broncho-pulmonary segment, is formed as a continuation of the vein draining the ventral subsegment. The latter is formed by a number of small tributaries which drain the subsegment and is to be found lying on the caudal medial aspect of the subsegmental bronchus (ACcv) (Plate LXIII). The cardiac segmental vein lies on the caudal medial aspect of the segmental bronchus (ACc), in a subpleural position, and runs in a dorsal and medial direction (Plate LXIII); near the point at which the cardiac segmental bronchus meets the apical segmental bronchus (ACa), the vein is positioned medial to the cardiac segmental bronchus, and it soon joins the apical segmental vein to form the apical-cardiac lobar vein (Plate LVI).

The segmental vein receives a number of cranial lateral and caudal lateral tributaries which drain the cranial lateral and caudal lateral subsegments; these veins lie in the planes between the subsegments, ventral to the subsegmental bronchi, and are formed in the usual way by a number of smaller tributaries. The cranial veins pass medial to the segmental bronchus before joining the segmental vein. (Plate LXIII).

<u>The left diaphragmatic lobar vein</u>: the diaphragmatic lobe of the left lung is drained by this vein. In its formation and course, it is similar to the diaphragmatic lobar vein in the right lung.

The apical broncho-pulmonary segment of the left diaphragmatic lobe is drained mainly by the apical segmental vein. This vein is formed on the medial aspect of the lobar bronchus (A)/

(A) by two veins, a cranial and a caudal, which drain the cranial and caudal subsegments of the apical segment; from this point, it passes in a ventral and cranial direction to enter the dorsal aspect of the diaphragmatic lobar vein (Plate LVII & LXVII). The cranial vein which drains the cranial subsegment lies in the connective tissue plane between the cranial and caudal subsegments, caudal and medial to the subsegmental bronchus (Acr); it is formed by several small tributaries, which lie between and drain the areas ventilated by the collateral bronchial rami, and also by tributaries which drain the adjacent parts of the caudal subsegment (Plate LXVII). The cranial vein then passes in a ventral and medial direction, lying caudal and medial to the segmental bronchus (A), to meet the vein draining the caudal subsegment and so form the segmental vein. The caudal vein lies caudal and medial to the caudal subsegmental bronchus (Aca), in the connective tissue plane between the apical and subapical segments of the diaphragmatic lobe, and runs in a cranial and ventral direction to meet the cranial vein (Plate LXVII). It is formed by several small lateral, medial and dorsal tributaries which drain the caudal subsegment and the adjacent part of the subapical segment, and it is joined by a larger lateral and a larger medial vein; the lateral vein lies in the connective tissue plane between the areas ventilated by the first and second lateral rami of the caudal subsegmental bronchus (Aca) and drains these areas and the adjacent part of the subapical segment (Plate LXIII); the medial vein drains the area ventilated/

ventilated by the bronchus (Acam) and the adjacent part of the subapical segment,and lies caudal to the bronchus in the plane between this area and the subapical segment (Plate LXVII).

The ventral basal segment is drained mainly by the ventral basal segmental vein which lies caudal and ventral to the segmental bronchus (VB) in the plane between the ventral basal and lateral basal segments of the diaphragmatic lobe (Plate LVI). This vein runs in a dorsal, medial and slightly cranial direction to pass over the ventral aspect of the lobar bronchus (D), in the plane between the ventral basal and medial basal segments, and enter the lateral aspect of the diaphragmatic lobar vein (Plate LVI). It is formed by the union of the cranial and caudal subsegmental veins which drain the cranial ventral and caudal ventral subsegments.

The caudal vein is formed by several tributaries which drain the various parts of the subsegment and the adjacent parts of the lateral basal segment; these tributaries converge towards the vein as it lies on the caudal medial aspect of the subsegmental bronchus (VBca) in the connective tissue plane between the subsegment and the lateral basal segment (Plate LVI & LXIV). On the level at which the segmental bronchus gives off the cranial ventral subsegmental bronchus (VBcr), the caudal vein is joined by the cranial vein which drains the cranial ventral subsegment.

The cranial vein lies caudal and medial to the subsegmental bronchus (VBcr) in the plane between the cranial ventral and the caudal ventral subsegments; it is formed by several tributaries/

tributaries which drain the cranial ventral subsegment and the adjacent part of the caudal ventral subsegment, and it runs in a dorsal and medial direction to meet the caudal vein (Plate LXIV).

The segmental vein receives a lateral vein which drains the dorsal lateral subsegment ventilated by the subsegmental bronchus (VB1) and the adjacent parts of the ventral basal and lateral basal segments. This lateral vein lies caudal to the subsegmental bronchus, in the plane between the lateral subsegment and the lateral basal segment, and runs in a medial and slightly ventral direction to join the segmental vein (Plate LVII & LXIV). The segmental vein also receives two medial veins, a proximal and a distal. The distal vein, which lies in the plane between the lateral basal segment and the medial subsegment of the ventral basal segment, receives tributaries which drain these adjacent areas of lung tissue, and passes in a cranial and dorsal direction to enter the segmental vein. The proximal vein, which lies in the plane between the ventral basal and medial basal segments, receives tributaries which drain the adjacent parts of these segments, and passes in a cranial and dorsal direction to enter the segmental vein (Plate LVI).

The subapical segment is drained mainly by the subapical segmental vein which is formed as the continuation of the vein draining the caudal dorsal subsegment. This subsegmental vein lies on the caudal medial aspect of the subsegmental bronchus, and it is formed in the usual way by a number of small/

small tributaries which drain the dorsal part of the subapical segment and the adjacent parts of the dorsal basal segment (Plate LVII & LXIV). The segmental vein lies caudal and medial to the segmental bronchus (SA) in the plane between the subapical and dorsal basal segments, and running in a cranial, ventral and slightly medial direction, it passes over the medial aspect of the lobar bronchus (D) to enter the dorsal aspect of the lobar vein (Plate LXVII). It receives a number of tributaries which drain the medial, lateral and dorsal subsegments of the subapical segment and the adjacent parts of the dorsal basal segment, and towards its termination, a medial and a lateral vein which lie caudal to the subsegmental bronchi (SAm1 & SAl1) which ventilate the medial and the cranial lateral subsegment (Plate LXIV & LXVII). A small vein, which lies in the plane between the first medial subsegment and the rest of the subapical segment and drains the adjacent areas of lung tissue, may be found in some lungs; it passes in a ventral and cranial direction to enter the dorsal aspect of the lobar vein.

The lateral basal segmental vein drains the greater part of the lateral basal broncho-pulmonary segment. It lies caudal to the segmental bronchus (LB), in the connective tissue plane between the lateral basal and dorsal basal segments, and running in a cranial, medial and slightly dorsal direction, it passes ventral to the dorsal basal segmental bronchus (DB) in the connective tissue plane between the medial basal, lateral basal and dorsal basal segments; it then joins the/

the dorsal basal segmental vein to form the diaphragmatic lobar vein on the medial ventral aspect of the lobar bronchus (D), just distal to the point at which the lobar bronchus gives off the lateral basal segmental bronchus (LB) and forms the dorsal basal segmental bronchus (DB). (Plate LVI & LXV).

The lateral basal segmental vein is formed by the cranial and caudal veins which drain the cranial ventral and caudal ventral subsegments. The caudal vein lies caudal and medial to the bronchus (LBca) in the plane between the lateral basal and dorsal basal segments; it receives a number of tributaries which drain the caudal ventral subsegment and the adjacent part of the dorsal basal segment. (Plate LVI, LVII & LXVII). The vein draining the cranial ventral subsegment lies caudal and medial to the bronchus (LBcr) in the plane between the cranial ventral and caudal ventral subsegments, and running in a dorsal and medial direction, it passes ventral to the caudal ventral subsegmental bronchus (LBca) to join the caudal subsegmental vein. The segmental vein is formed just distal to the point at which the segmental bronchus (LB) divides into the cranial ventral (LBcr) and caudal ventral (LBca) subsegmental bronchi (Plate LVI & LXV).

The lateral basal segmental vein receives lateral and medial veins which drain the lateral and medial subsegments ventilated by the bronchi (LBl1, LBl2 & LBm1). These subsegmental veins are formed by tributaries which drain their respective subsegments and the adjacent parts of the lateral basal and dorsal basal segments, and they lie caudal to their respective/

respective bronchi in the connective tissue planes between the subsegments and the dorsal basal segment (Plate LVI & LXV). The lateral veins run in a cranial, ventral and medial direction and the ventral veins in a cranial, dorsal and medial direction to join the segmental vein.

The medial basal broncho-pulmonary segment is drained by the medial basal segmental vein; this is formed by a number of medial, lateral, dorsal and ventral tributaries which drain the caudal, dorsal and ventral subsegments. It lies caudal and medial to the segmental bronchus (MB) in the connective tissue plane between the medial basal and dorsal basal segments, and passes in a cranial, dorsal and slightly medial direction to enter the lobar vein (Plate LVI & LXVII).

The dorsal basal broncho-pulmonary segment is drained mainly by the dorsal basal segmental vein which lies ventral and medial to the segmental bronchus (DB). The vein passes in a cranial direction, and just distal to the level at which the lateral basal segmental bronchus (LB) is given off by the lobar bronchus (D), it is joined by the lateral basal segmental vein, and together they form the diaphragmatic lobar vein (Plate LVI). The segmental vein is formed by the union of the medial and lateral veins which drain the medial and lateral terminal subsegments. These veins lie ventral to their respective bronchi (DBmt & DBlt) and unite ventral to the medial terminal subsegmental bronchus (DBmt), just distal to the point at which it is given off by the segmental bronchus (DB).

During/

During its course, the segmental vein receives several veins which lie between and drain the subsegments, and towards its termination larger veins which drain the dorsal, ventral, medial and lateral subsegments ventilated by the bronchi (DBd1, DBv1, DBm1 & DBl1) (Plate LXVI & LXVII). The lateral vein lies caudal and medial to the bronchus (DBl1) in the plane between the lateral subsegment and the adjacent part of the dorsal basal segment, and receiving numerous smaller tributaries, it runs in a cranial, dorsal and medial direction passing ventral to the segmental bronchus (DB) to join the segmental vein (Plate LXVI). The medial vein lies caudal and medial to the bronchus (DBm1) in the plane between the medial subsegment and the dorsal basal segment, and it passes in a cranial, lateral and dorsal direction to join the segmental vein (Plate LXVII). The dorsal vein lies caudal and medial to the bronchus (DBd1) in the plane between the dorsal subsegment and the adjacent part of the dorsal basal segment, and it passes in a cranial, ventral and medial direction over the medial aspect of the segmental bronchus (DB) to join the segmental vein. The ventral vein lies caudal and medial to the bronchus (DBv1) in the plane between the ventral subsegment and the adjacent part of the dorsal basal segment, and passing in a dorsal and cranial direction, it joins the segmental vein (Plate LXVI & LXVII).

To summarise, following a study of the lungs of thirteen sheep by means of dissections and corrison casts, and by serial sections of the right cardiac lobe of one of these, the larger veins/

veins have been described with attention to the areas which they drain. The pulmonary veins may be classed as superficial or deep. The superficial veins are situated in a subpleural position, while the deep veins lie in the connective tissue planes which exist between the various large and small independent areas of lung tissue.

Generally speaking, the larger the area of lung tissue the more independent it is with regard to its venous drainage. The right and left lungs are completely independent; the right lung is drained by the right apical lobar vein, the right cardiac lobar vein and the right diaphragmatic lobar vein; the left lung by the apical-cardiac lobar vein and the left diaphragmatic lobar vein. These veins open into the left atrium of the heart.

The lobes are practically independent as regards their venous drainage except for small veins which lie in the connective tissue planes between the lobes, drain narrow adjacent areas of these lobes and then enter one of the lobar veins. The lobes are drained by the above mentioned lobar veins, the right intermediate lobe being drained by the intermediate lobar vein which opens into the right diaphragmatic lobar vein shortly before the latter enters the left atrium.

The lobar veins are formed by the segmental veins which drain the various broncho-pulmonary segments within the lobe. The broncho-pulmonary segments are less independent with regard to their venous drainage than the lobes. Each segment is drained by numerous tributaries; these drain the various parts of/

of the segment, and the majority usually conjoin to form a single vein which lies either in the connective tissue plane between the segment and an adjacent segment, or in a sub-pleural position. The parts of the segment which lie furthest from this vein and adjacent to a distant neighbouring segment, are drained by tributaries which enter the vein lying in the connective tissue plane between the segment and this distant segment. A segment whose boundaries are mostly subpleural, is more independent with regard to its venous drainage than a segment whose boundaries adjoin neighbouring segments, because nearly all the tributaries enter one segmental vein.

The subsegments are generally less independent than the segments with regard to their venous drainage, because they usually present less of their boundary to the surface of the lung. However, in most cases, the vein which drains the greater part of a subsegment can be recognised. The majority of these veins are deep veins and lie in the connective tissue planes.

The veins have been named after the areas which they are largely responsible for draining. This method is not strictly accurate in respect to the broncho-pulmonary segments and subsegments but, providing that it is remembered that a particular area is not drained solely by one vein, it simplifies the description.

The veins are to be found lying on the caudal aspect of the bronchi which run transversely or oblique to the long axis/

axis of the lungs, and on the medial aspect of the bronchi which run parallel to the long axis of the lungs.

Discussion.

Many of the points raised in this study have been discussed in their appropriate sections, however, it is important to emphasise the great difficulty in regard to the terminology which has to be overcome in a description of the lungs. The terms "lobe", "broncho-pulmonary segment", "subsegment" and "pulmonary lobule" are all used to describe areas of pulmonary tissue.

The term "pulmonary lobule" has been described by Miller (1947) as the area ventilated by a respiratory bronchiole and its divisions, and he has called it the unit of lung structure. This is highly satisfactory because then there can be no doubt as to what is meant by a pulmonary lobule. Sisson and Grossman (1953), however, describe a pulmonary lobule as the area ventilated by a lobular bronchiole which, they say, branches to form respiratory bronchioles. Therefore, the pulmonary lobule as described by Miller is a much smaller and more definite area and, in the opinion of the writer, should be accepted as the unit of lung structure.

Unfortunately the other terms do not appear to have been described with the same attention to detail by authors in general. For instance, in the sheep, the lungs have been divided into lobes by fissures, but no attempt seems to have been made to correlate these external divisions with the divisions of the bronchial tree. Sisson and Grossman (1953) and/

and Ellenberger and Baum (1932) describe the left lung as consisting of three lobes and the right lung of four or five lobes. d'Hardiviller (1897) and Bressou and Vladutiu (1939) consider that the left lung consists of two lobes and the right lung of four lobes. Chauveau (1890) and Paul Martin (1904) also consider that the left lung consists of two lobes, but Martin states that this is dependent on the cardiac lobe being joined to the diaphragmatic lobe.

Following a survey of one hundred and fifty lungs of sheep to determine the size and form of the lobes, it was evident that well marked variations from the usual descriptions do occur. Fissures may be larger, smaller or even absent, and in fact, if the lobation is to be decided on the external appearance of the lungs, one pair of lungs examined would be described as consisting of one lobe in the left lung and three lobes in the right lung.

The fissures, which form the external demarcations of lobes, are produced by the breakdown of the connective tissue planes which lie between independent areas of lung tissue, and their presence or absence in any particular species would appear to depend on a number of factors which have already been discussed when describing the lobation of the lungs.

The correct use of the terms "broncho-pulmonary segment" and "subsegment" is dependent on the term "lobe" being understood. A broncho-pulmonary segment is now generally accepted as being a relatively large area of the lung which is ventilated by a bronchus opening from a lobar bronchus. Similarly, a/

a subsegment is a relatively large area of lung tissue which is ventilated by a bronchus opening from a segmental bronchus. Therefore, unless it is made quite clear what is meant by the term "lobe", the terms "segment" and "subsegment" are meaningless.

On this account the author has felt it necessary to give a definition of a pulmonary lobe, based on the external appear -ance of the lung and the divisions of the bronchial tree. A pulmonary lobe may be defined as a large area of pulmonary tissue which is ventilated by a large bronchus arising from either a main bronchus or from the trachea; it is separated from neighbouring lobes by interlobar fissures which may be continued by connective tissue planes, and it is independent with regard to its ventilation, arterial supply and venous drainage. Based on this definition the right lung is described as consisting of four lobes, an apical, a cardiac, an intermediate and a diaphragmatic, and the left lung of two lobes, an apical-cardiac, and a diaphragmatic. The two lobes which are subject to varied descriptions, are the apical lobe of the right lung and the apical-cardiac lobe of the left lung; they are both ventilated by a single bronchus, and therefore they cannot be subdivided into further lobes. The external demarcations, which in each case suggest the presence of two lobes, in actual fact mark the boundaries of broncho-pulmonary segments.

Having established the number of lobes, the lungs are further subdivided into broncho-pulmonary segments; it may be argued/

argued that the description in this paper is not as it should be and that there should be more segments as suggested by Bressou and Vladutiu (1939). As mentioned in the description, the licence to use one's discretion is given by Appleton (1945) when he states: "The term bronchopulmonary segment has been restricted arbitrarily to those relatively large portions of lung which are ventilated by bronchi that have orificies into one of the lobar bronchi". In this study an attempt has been made to simplify the description of the broncho-pulmonary segments as much as possible, and at the same time to follow the scheme approved for the human lung. However, there are some who may be of the opinion that the area described as the dorsal basal segment should have been divided into further segments, but it is felt that it is better to consider the area as a single segment, because the bronchi which arise from the diaphragmatic lobar bronchi after it has given off the earlier segmental bronchi are subject to more variation, and therefore are more likely to cause confusion.

Similarly discretion has been used in the further subdivision of the segments into subsegments.

To summarise in any description of the lobar, broncho-pulmonary segmental and subsegmental anatomy of the lungs, it is necessary to establish first what is meant by the term "pulmonary lobe" because the further division of the lungs into broncho-pulmonary segments and subsegments is primarily dependent on the definition of a lobe.

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Serial sections of the cardiac lobe of the right lung (Sheets 1 - 14).

Abbreviations.

C. Cardiac Lobar bronchus.

L. Lateral segmental bronchus.

Ld. Dorsal subsegmental bronchus of the lateral segment.

Ll. Lateral subsegmental bronchus of the lateral segment.

Lca. Caudal subsegmental bronchus of the lateral segment.

Lv. Ventral subsegmental bronchus of the lateral segment.

Lcr. Cranial subsegmental bronchus of the lateral segment.

M. Medial segmental bronchus.

Mcr1. 1st cranial subsegmental bronchus of the medial segment.

Mcr1d. Dorsal ramus of the cranial subsegmental bronchus.

Mca. Caudal subsegmental bronchus of the medial segment.

Mcal1. 1st lateral ramus of the caudal subsegmental bronchus.

Ml1. Lateral subsegmental bronchus of the medial segment.

Mmid. Middle subsegmental bronchus of the medial segment.

Mmidm. Medial ramus of the middle subsegmental bronchus.

Mcr2. 2nd cranial subsegmental bronchus of the medial segment.

Mmed. Medial subsegmental bronchus of the medial segment.

Ml. Lateral subsegmental bronchus of the medial segment.


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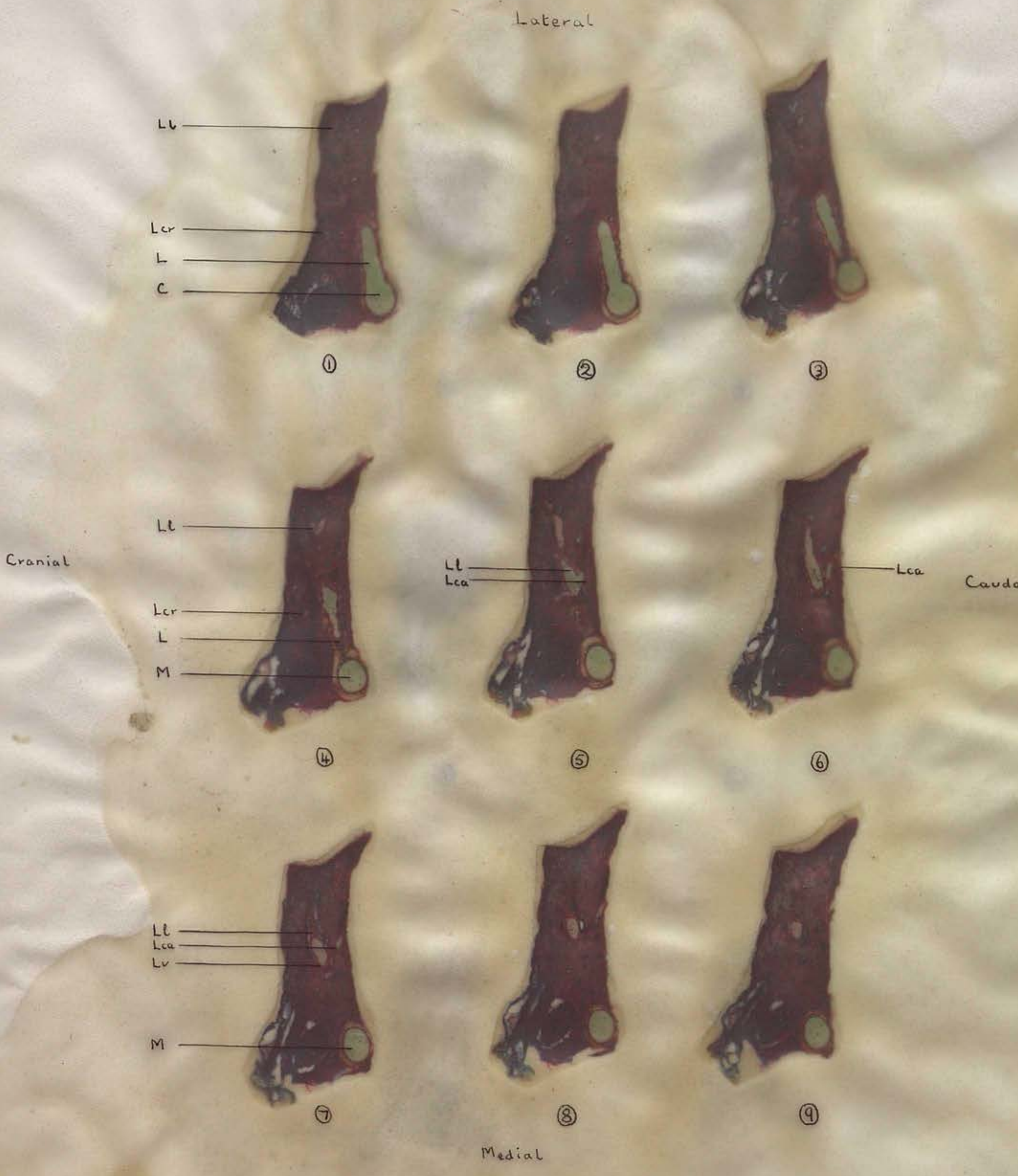
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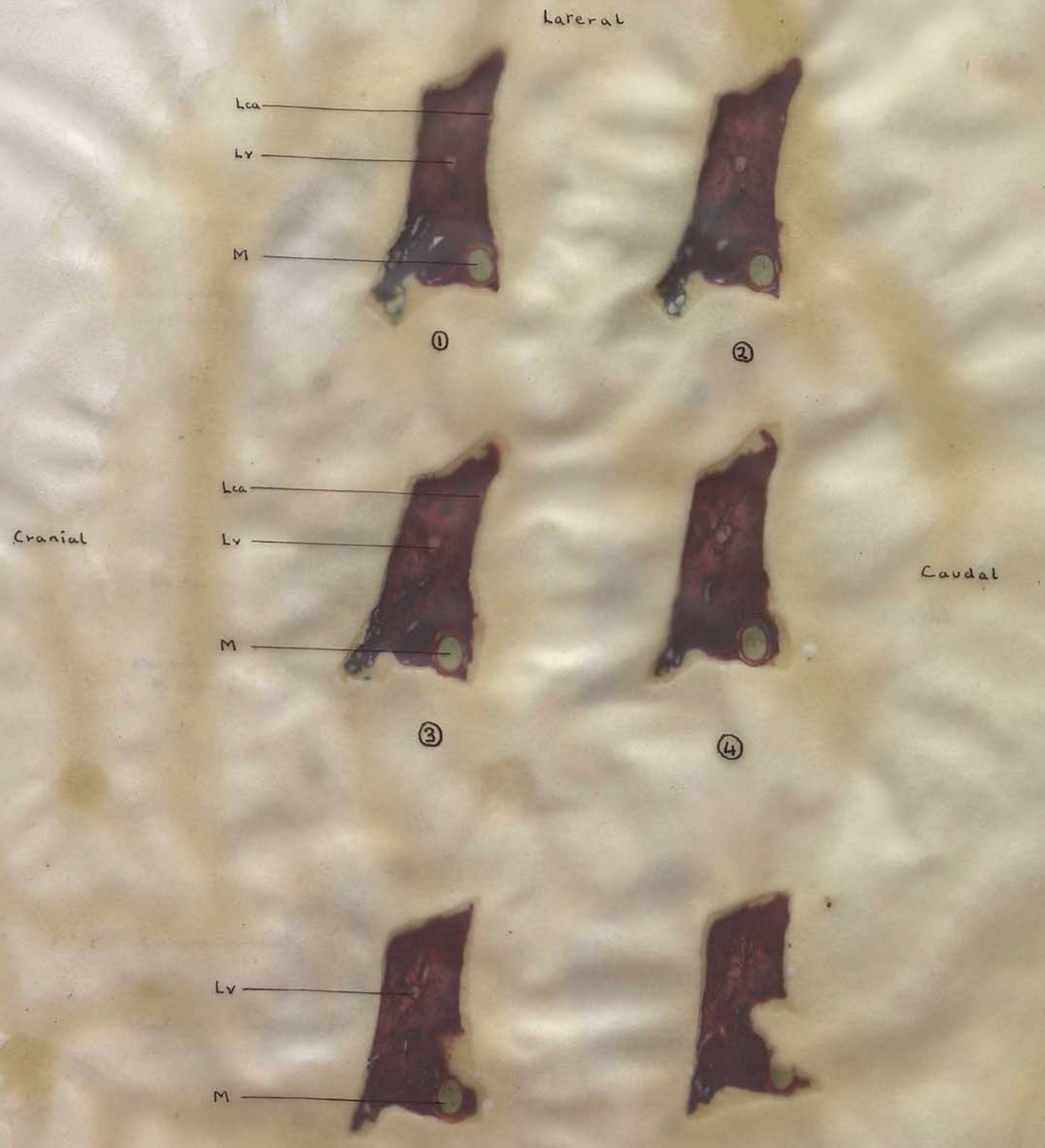

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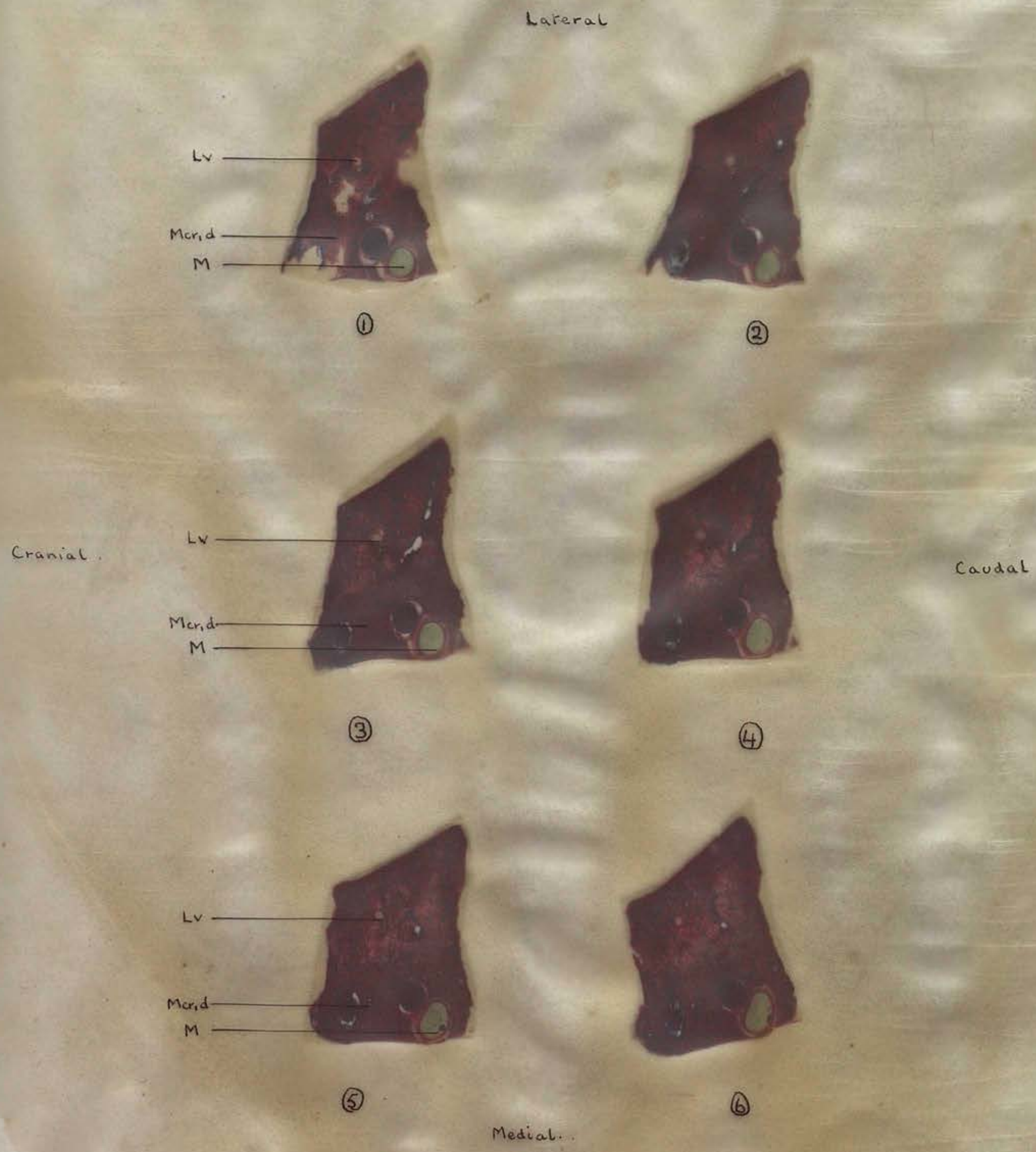
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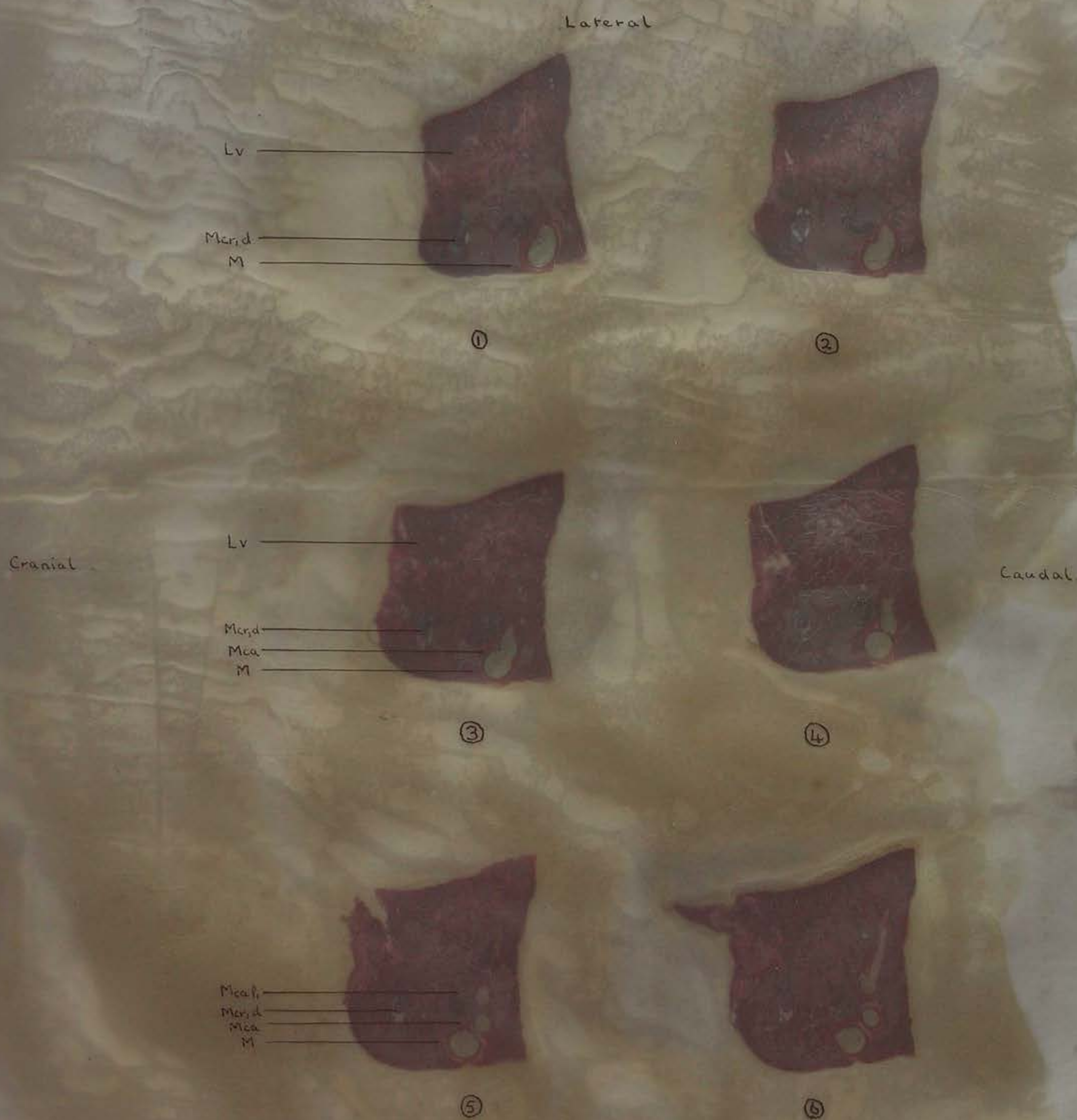
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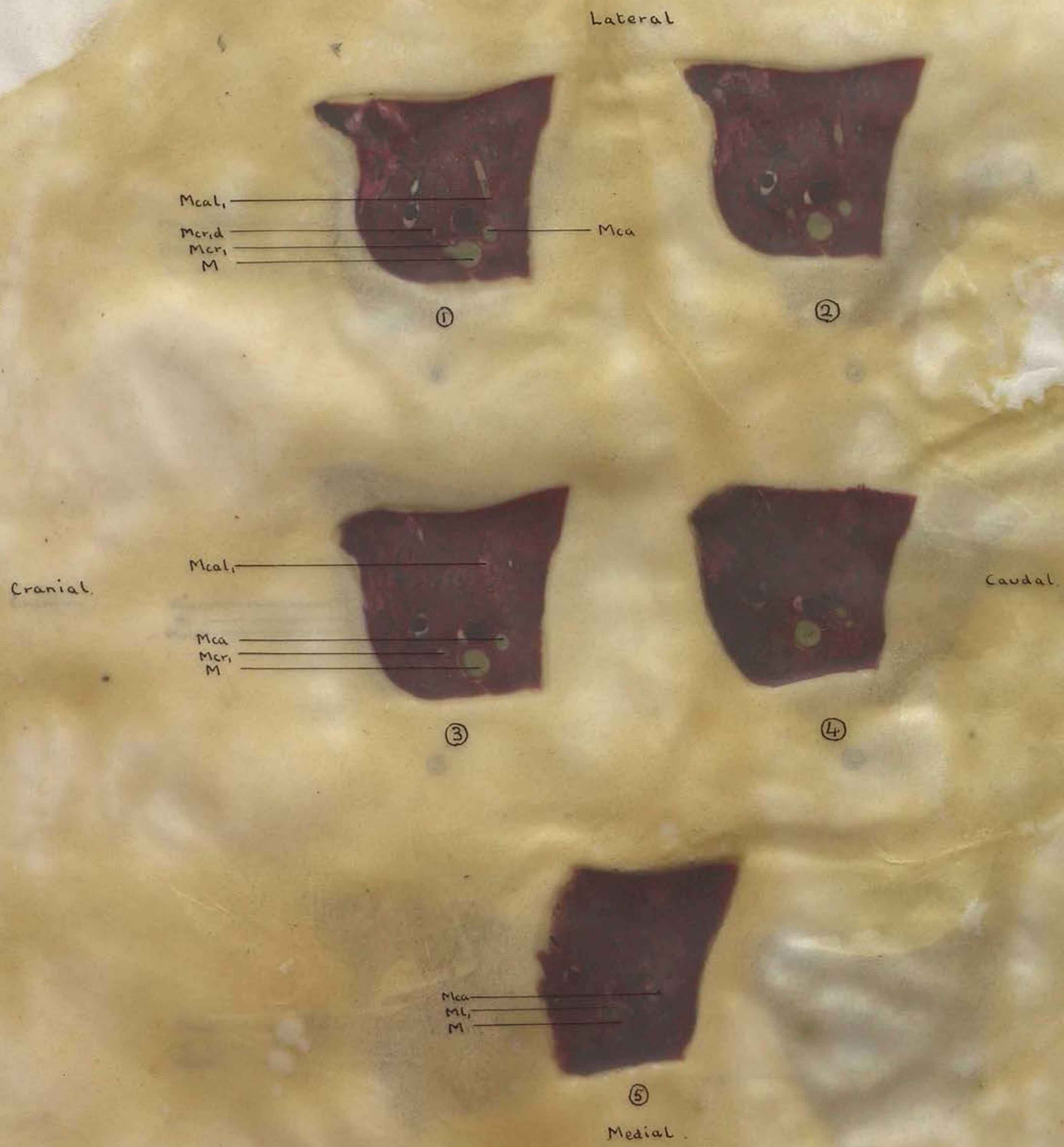
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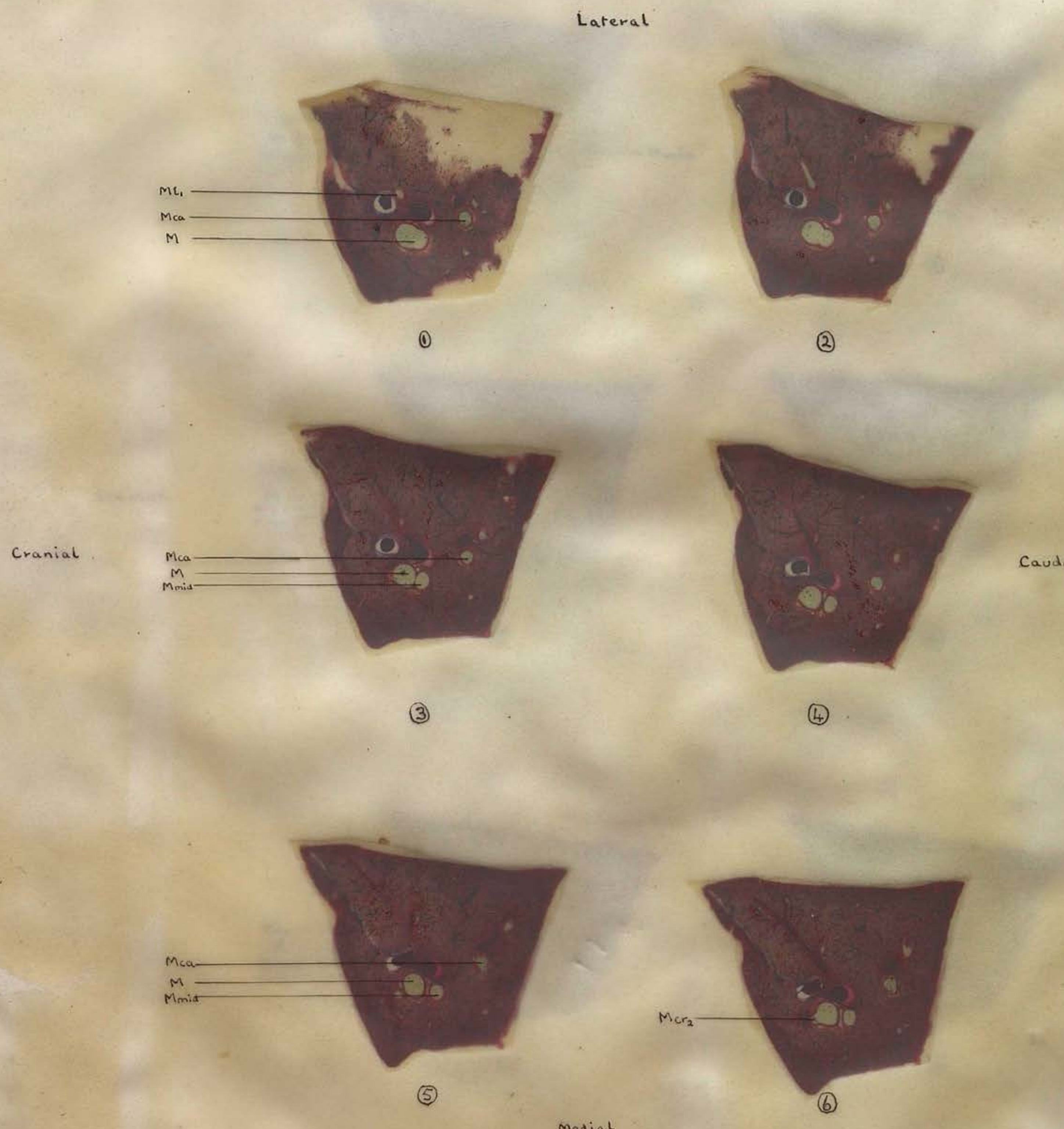
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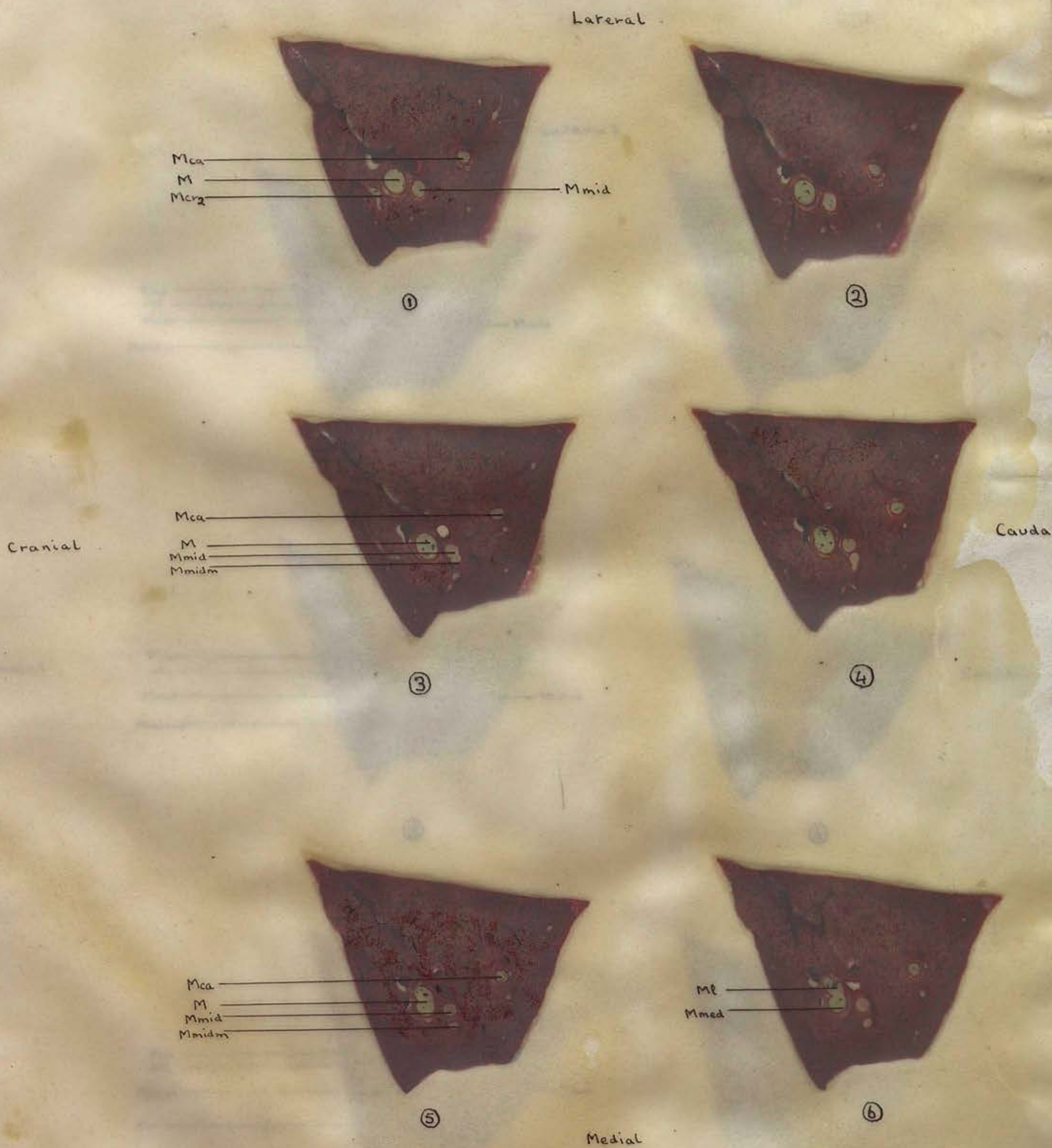

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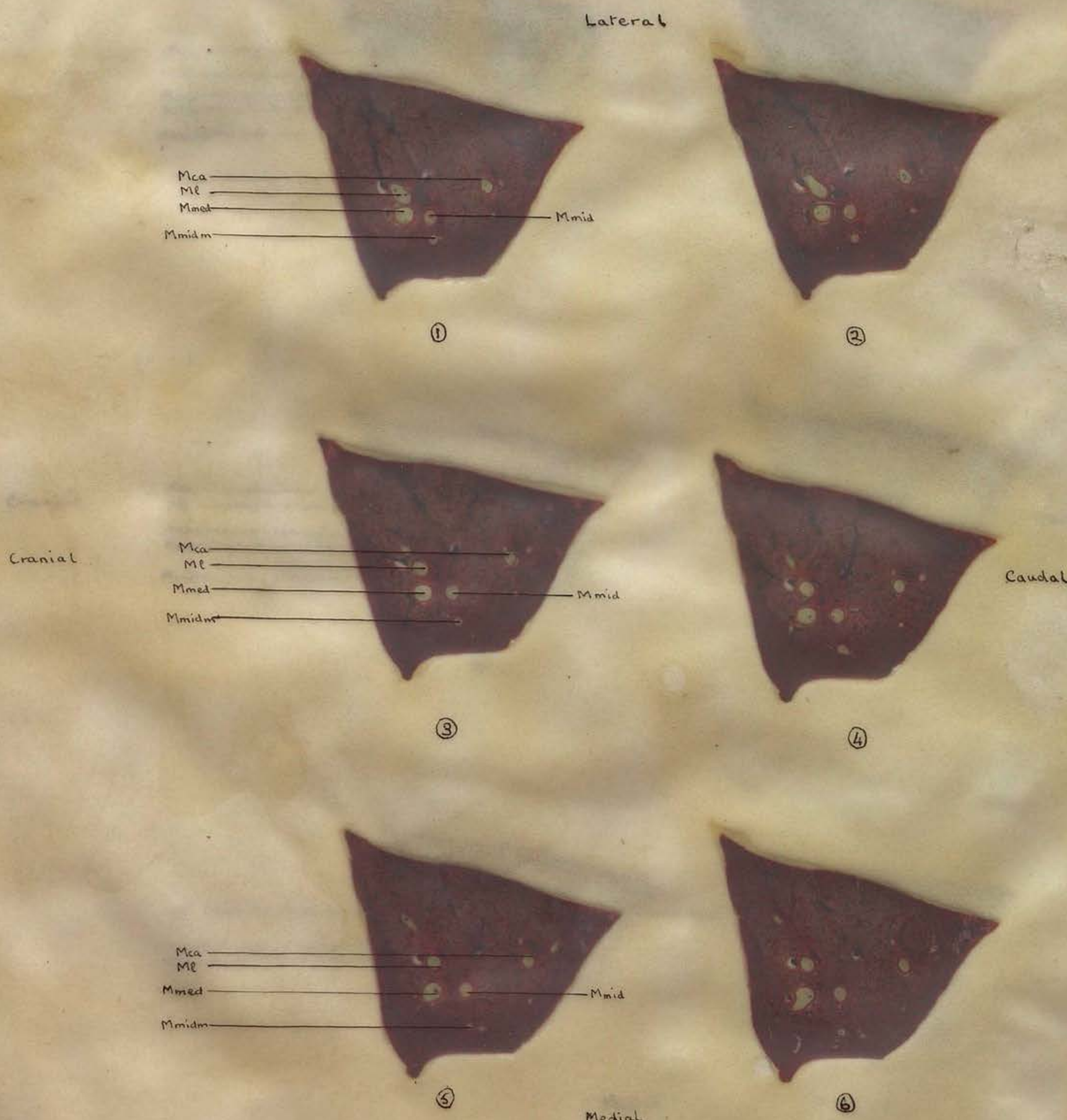
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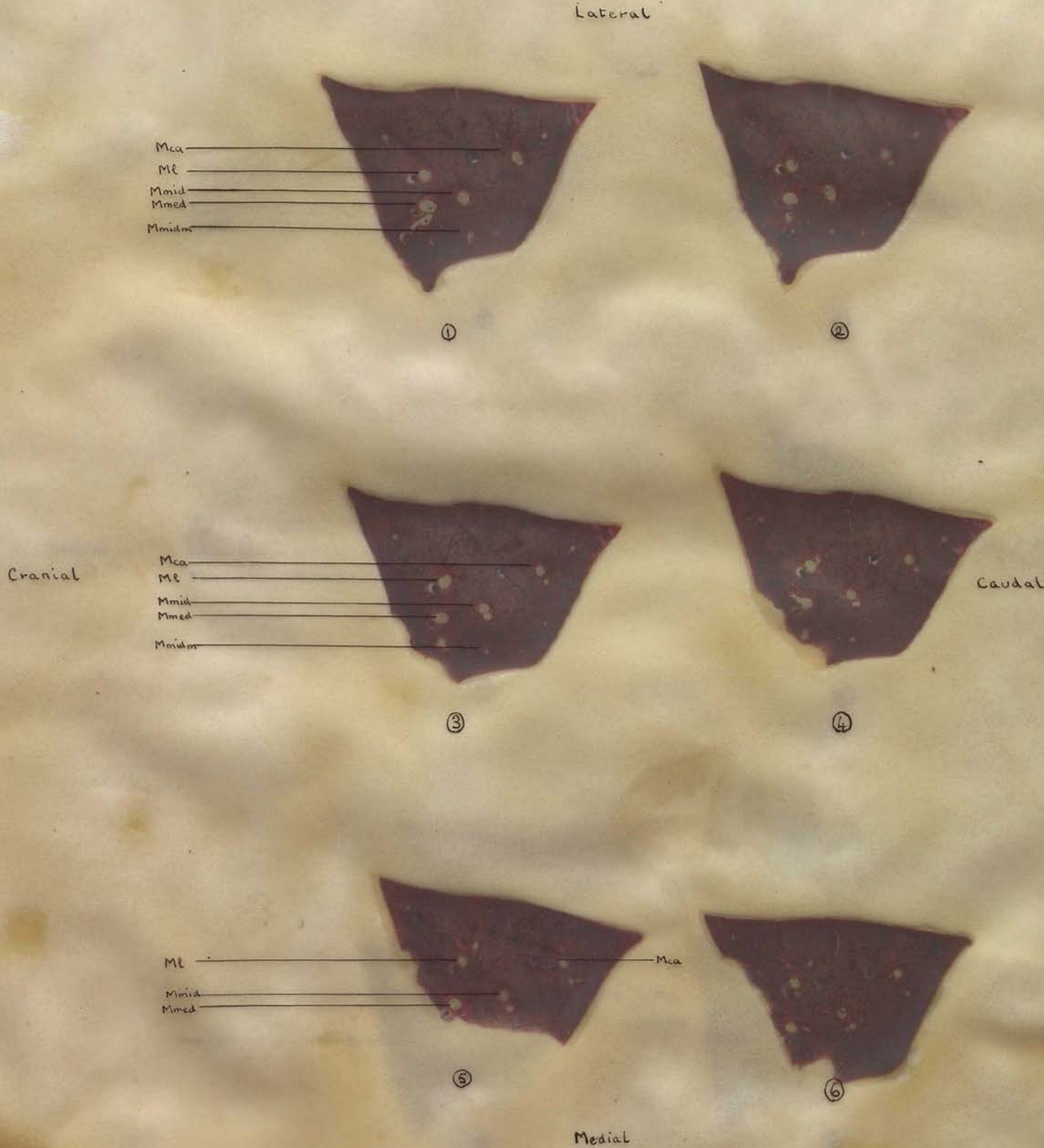
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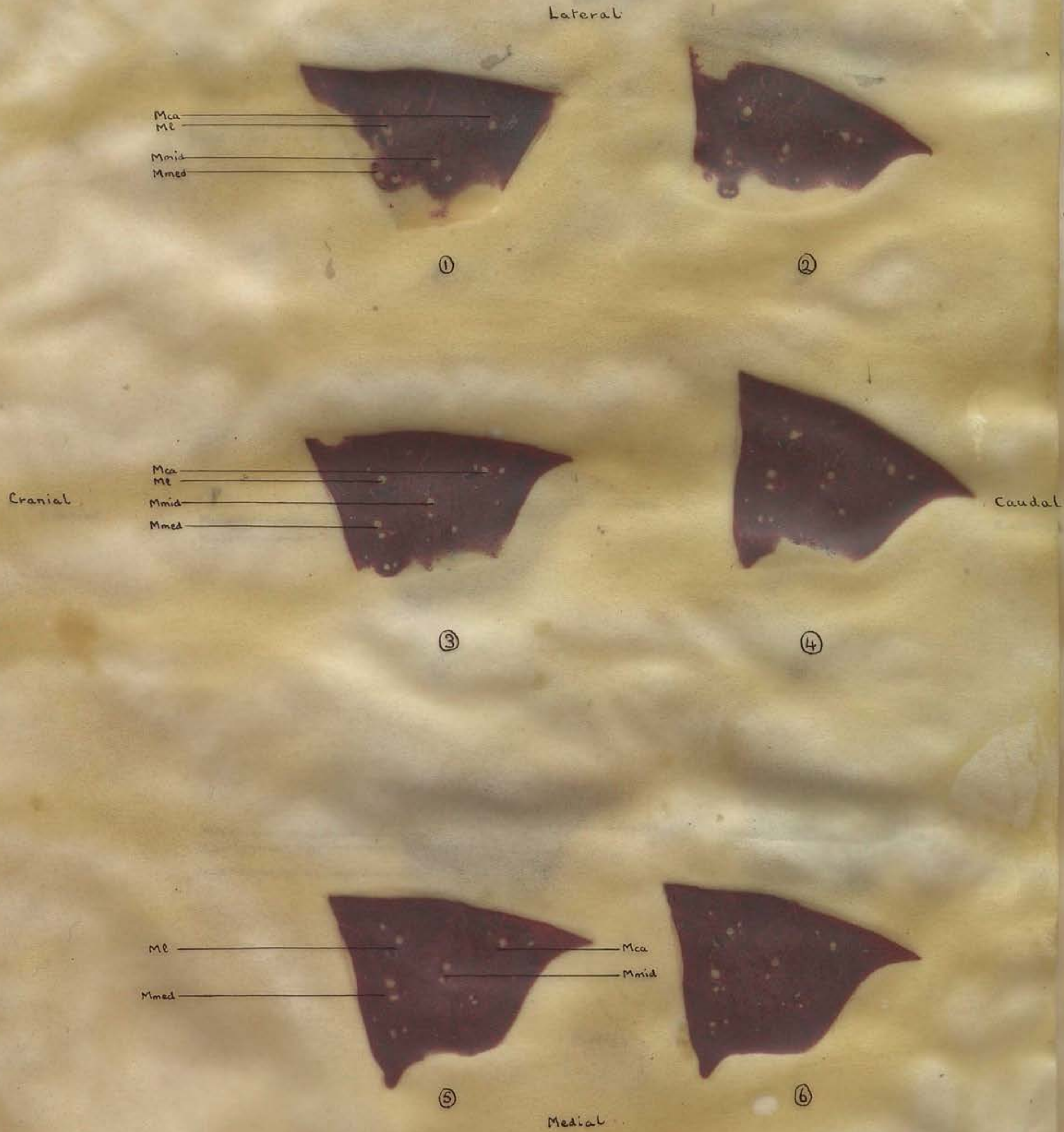

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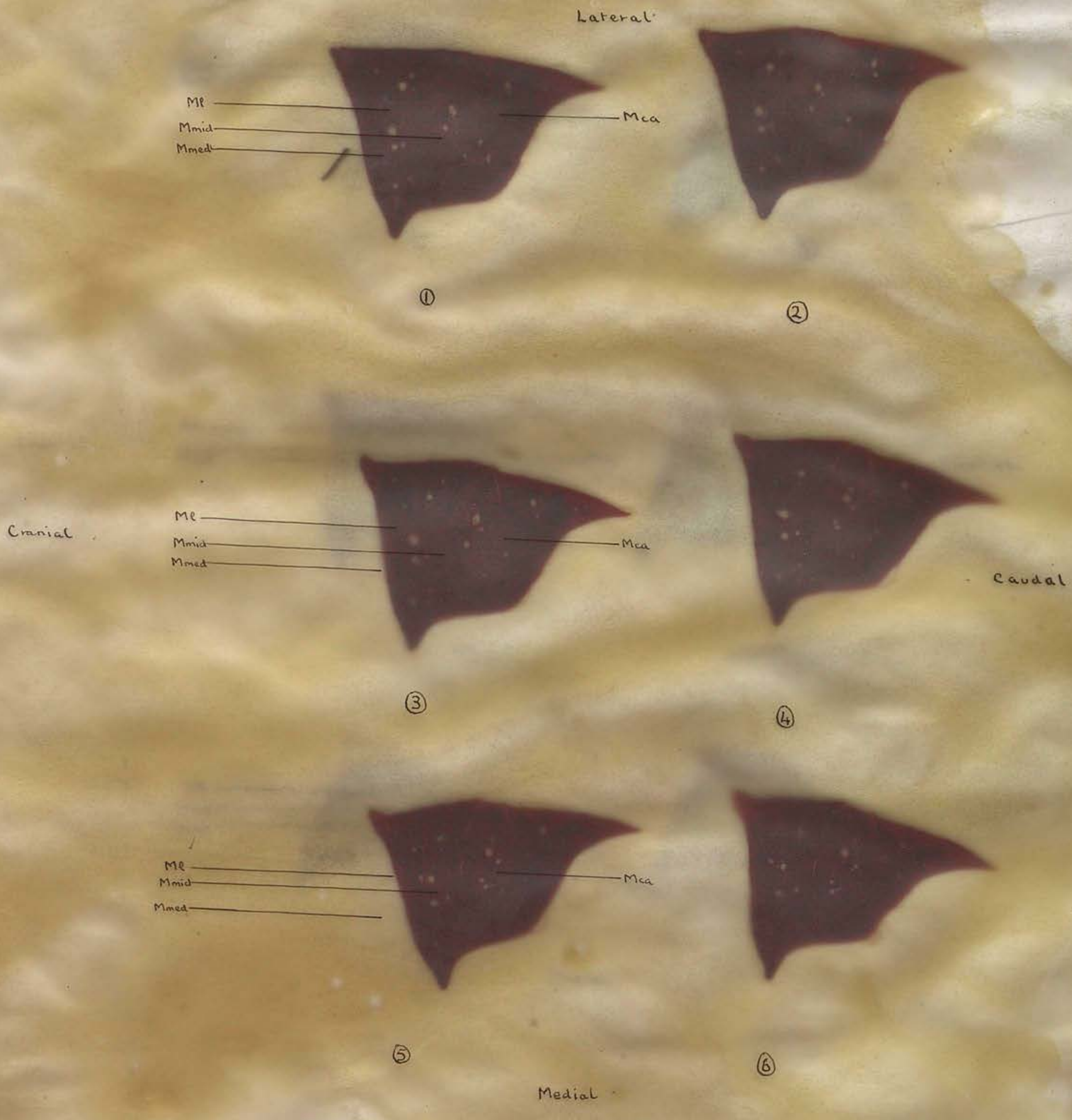
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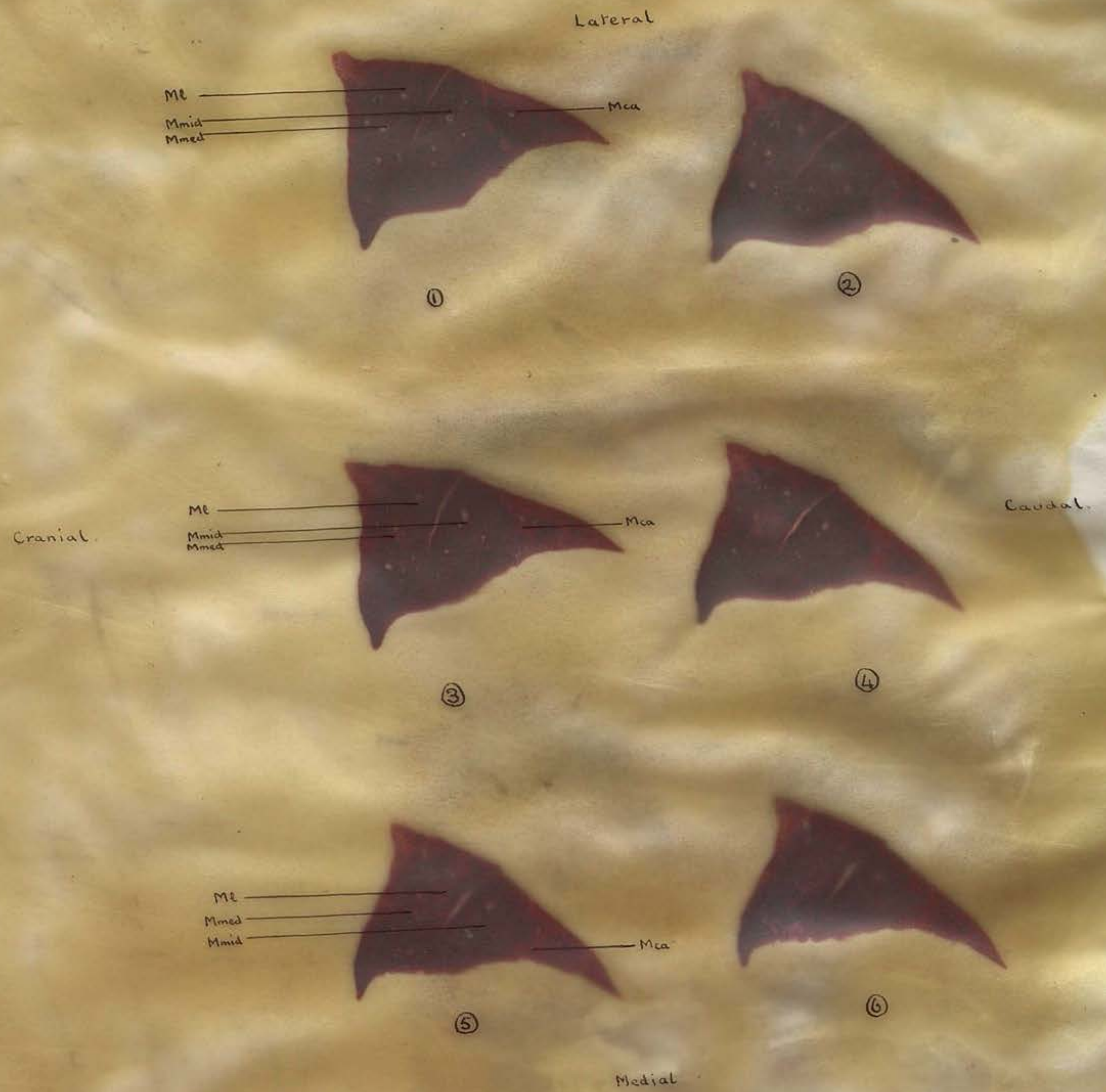
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